

**12th INTERNATIONAL CONFERENCE
ON STRUCTURAL ANALYSIS
OF HISTORICAL CONSTRUCTIONS**

SAHC 2021

Online event, 29 Sep - 1 Oct, 2021

P. Roca, L. Pelà and C. Molins (Eds.)



**12th INTERNATIONAL CONFERENCE
ON STRUCTURAL ANALYSIS
OF HISTORICAL CONSTRUCTIONS**

SAHC 2021

Online event, 29 Sep - 1 Oct, 2021

A publication of:

**International Centre for Numerical
Methods in Engineering (CIMNE)**

Barcelona, Spain



ISBN: 978-84-123222-0-0

Printed by: Artes Gráficas Torres S.L., Huelva 9, 08940 Cornellà de Llobregat,
Spain

TABLE OF CONTENTS

Preface	7
Supporting Organizations.....	9
Organizers and Committees	11
Sponsors	15
Summary	17
Contents	19
Presented Sessions.....	45
Authors Index.....	3661

PREFACE

The International Conference on Structural Analysis of Historical Constructions (SAHC) was first celebrated in Barcelona in 1995, followed by a second edition also in Barcelona in 1998. Since then, nine subsequent editions have been organized in different countries of Europe, America and Asia. The SAHC conference series is intended to offer a forum allowing engineers, architects and all experts to share and disseminate state-of-art knowledge and novel contributions on principles, methods and technologies for the study and conservation of heritage structures. Through all its successful past editions, the SAHC conference has become one of the topmost periodical opportunities for scientific exchange, dissemination and networking in the field.

During the last decades the study and conservation of historical structures has attained high technological and scientific standards. Today's practice involves the combination of innovative non-destructive inspection technologies, sophisticated monitoring systems and advanced numerical models for structural analysis. More than ever, it is understood that the studies must be performed by interdisciplinary teams integrating wide expertise (engineering, architecture, history, archeology, geophysics, chemistry...). Moreover, the holistic nature of the studies, and the need to encompass and combine the different scales of the problem –the materials, the structures, the building aggregates, and the territory – are now increasingly acknowledged. Due to all this, the study of historical structures is still facing very strong challenges that can only be addressed through sound international scientific cooperation.

Taking these ideas in mind, the 12th edition of the SAHC conference aimed at creating a new opportunity for the exchange and discussion of novel concepts, technologies and practical experiences on the study, conservation and management of historical constructions.

The present proceedings include the papers presented to the conference, which was finally celebrated on September 29-30 and October 1, 2021, in an on-line mode due to the world sanitary emergency situation created by the Covid-19 pandemic.

The conference included the following topics: history of construction and building technology; inspection methods, non-destructive techniques and laboratory testing; numerical modeling and structural analysis; structural health monitoring; repair and strengthening strategies and techniques; conservation of 20th c. architectural heritage; seismic analysis and retrofit; vulnerability and risk analysis and interdisciplinary projects and case studies.

The SAHC 2021 conference has been possible thanks to the large contribution of the scientific committee and reviewer panel who took care of selecting and review the papers submitted. The contribution of the different sponsors and supporting organizations is also acknowledged. Above all, the conference has been possible thanks to all the authors who have contributed with very valuable papers despite the difficulties caused by the world pandemic. New editions of the conference are already planned in normal face-to-face formats which, in the upcoming years, will provide new opportunities for sharing valuable knowledge and experience on structural conservation, as well as for keeping alive and fulfilling the purpose and aims of the SAHC conference series.

The Organizing Committee

SUPPORTING ORGANIZATIONS



**UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH**

Universitat Politècnica de Catalunya
(UPC), Barcelona, Spain

CIMNE 



Center for Numerical Methods in
Engineering (CIMNE), UPC, Spain



ICOMOS
international council on monuments and sites

International Council on Monuments
and Sites (ICOMOS)


Iscarsah
International Scientific Committee on the Analysis and
Restoration of Structures of Architectural Heritage

International Scientific Committee for
Analysis and Restoration of Structures
of Architectural Heritage of ICOMOS
(ICOMOS / ISCARSAH)

ORGANIZERS AND COMMITTEES

Organizing Committee



Pere Roca

Technical University of Catalonia



Climent Molins

Technical University of Catalonia



Luca Pelà

Technical University of Catalonia



Paulo Lourenço

University of Minho



Claudio Modena

University of Padova

SCIENTIFIC COMMITTEE

National Members

- Jose M. Adam, Polytechnic University of Valencia
- Ernest Bernat, Polytechnic University of Catalonia
- Pedro Calderón, Polytechnic University of Valencia
- Miguel Cervera, Polytechnic University of Catalonia
- Victor Compán, University of Seville
- Leire Garmendia, University of the Basque Country
- Lluís Gil, Polytechnic University of Catalonia
- Pilar Giráldez, University of Barcelona
- Salvador Ivorra, University of Alicante
- Miquel Llorens, University of Girona
- Ignacio Lombillo, University of Cantabria
- Camilla Mileto, Polytechnic University of Valencia
- Javier Mosteiro, Technical University of Madrid
- Belén Riveiro, University of Vigo
- Savvas Saloustros, Polytechnic University of Catalonia
- Fernando Vegas, Polytechnic University of Valencia
- Marius Vendrell, University of Barcelona

International Members

- Rafael Aguilar, Pontifical Catholic University of Peru
- Takayoshi Aoki, Nagoya City University
- Alessandra Aprile, University of Ferrara
- Oriol Arnau, National Autonomous University of Mexico
- Görün Arun, Yildiz Technical University
- Hiram Badillo, Autonomous University of Zacatecas
- Andrea Benedetti, University of Bologna
- Rita Bento, University of Lisbon
- Katrin Beyer, Swiss Federal Institute of Technology in Lausanne
- Rubén Boroscchek, University of Chile
- Guido Camata, University of Chieti-Pescara
- Claudia Cancino, Getty Conservation Institute
- Eva Coïsson, University of Parma
- Dina D'Ayala, University College London
- Gianmarco de Felice, Roma Tre University
- Gianfranco de Matteis, University of Campania
- Matthew DeJong, University of California at Berkeley
- Milos Drdácáký, Institute of Theoretical and Applied Mechanics
- Khalid El Harrouni, National School of Architecture
- Ahmed Elyamani, Cairo University
- Yohei Endo, Shinshu University
- Mariana Esponda, Carleton University
- Antonio Formisano, University of Naples Federico II
- Dora Foti, University of Bari
- Enrico Garbin, University of Padova
- Giorgia Giardina, University of Cambridge

- Toshikazu Hanazato, Mie University
- Mehrdad Hejazi, University of Isfahan
- Marcela Hurtado, Federico Santa María Technical University
- Jason Ingham, University of Auckland
- Wolfram Jager, Technical University Dresden
- Stephen J. Kelley, SJK Inc.
- Debra Laefer, New York University
- Sergio Lagomarsino, University of Genova
- Alessandra Marini, University of Bergamo
- Guillermo Martínez, Michoacan University of Saint Nicholas of Hidalgo
- Arun Menon, Indian Institute of Technology Madras
- Gabriele Milani, Polytechnic University of Milan
- John Ochsendorf, Massachusetts Institute of Technology
- Daniel Oliveira, University of Minho
- Fernando Peña, National Autonomous University of Mexico
- Andrea Penna, University of Pavia
- Maurizio Piazza, University of Trento
- Mariapaola Riggio, Oregon State University
- Jan Rots, Delft University of Technology
- Antonella Saisi, Polytechnic University of Milan
- Cristián Sandoval, Pontifical Catholic University of Chile
- Vasilis Sarhosis, The University of Leeds
- Yaacov Schaffer, Israel Antiquities Authority
- Nigel Shrive, University of Calgary
- Marek Sklodowski, Institute of Fundamental Technological Research
- Pierre Smars, National Yunlin University of Science and Technology
- Luigi Sorrentino, Sapienza University of Rome
- Enrico Spacone, University of Chieti-Pescara
- Nicola Tarque, Pontifical Catholic University of Peru
- Adrienn Tomor, University of the West of England
- Daniel Torrealva, Pontifical Catholic University of Peru
- Maria Rosa Valluzzi, University of Padova
- Koenraad Van Balen, KU Leuven
- Humberto Varum, University of Porto
- Els Verstryngge, KU Leuven
- Elizabeth Vintzileou, National Technical University of Athens
- Roko Žarnić, University of Ljubljana

REVIEWER PANEL

- Daniela Addessi
- Maurizio Angelillo
- Jesus Bairán
- Elisa Bertolesi
- Maria Bostenaru
- Giuseppe Brando
- Manuel Buitrago Moreno
- Albert Cabané
- Chiara Calderini
- Ivo Calì
- Lorenzo Cantini
- Silvia Caprili
- Giuliana Cardani
- Claudia Casapulla
- Rosario Ceravolo
- Francesca Ceroni
- Francesco Clementi
- Camilla Colla
- Cossima Cornadó
- Sara Dimovska
- Anastasios Drougkas
- Chiara Ferrero
- Virginia Flores Sasso
- Aguinardo Fraddosio
- Donald Friedman
- Stefano Galassi
- Larisa García-Ramonda
- Lucia Garijo
- Carmelo Gentile
- Lorenzo Jurina
- Philip Karklbrenner
- David López
- Jose Machado
- Nirvan Makoond
- Nuno Mendes
- Andronki Miltiadou
- Bernt Mittnacht
- Tom Morrison
- Marius Mosoarca
- Juan Murcia
- Federica Ottoni
- Bartolomeo Pantò
- Marisa Pecce
- Chiara Pepi
- Elisa Poletti
- Bora Pulatsu
- Enrico Quagliarini
- Luisa Rovero
- Nicola Ruggieri
- Santiago Sanchez
- Mario Santana
- Michel Schuller
- Jorge Segura
- Vincenzo Sepe
- Alberto Taliercio
- Dimitris Theodossopoulos
- Filippo Ubertini
- Giuseppina Uva
- Graça Vasconcelos
- Maria Belén Jiménez

SPONSORS

PRO_SAM is a plugin which connects PRO_SAP with SAM II solver, a powerful tool for pushover analysis of new and existing structures.

SOLVER RELIABILITY

SAM II, conceived by Prof. Magenes, Eng. Manzini and Eng. Morandi, is a well-known and robust non-linear solver highly referenced in international literature.

CODES OF PRACTICE

Eurocode 8, Italian codes.

MATERIALS

Unreinforced and reinforced masonry, reinforced concrete and generic linear materials.

LOCAL FAILURE MECHANISMS

Automatic geometry interfacing with PRO_CineM for kinematic linear and non-linear analyses.

LINEAR ANALYSIS

Automatic generation of plate and shell linear model from the equivalent frame.

FREE

PRO_SAM is free for students, scholars or scientific research.



Asdea Software S.r.l. is part of the burgeoning ASDEA brand, which includes ASDEA S.r.l. and ASDEA Hardware. We are a software development company staffed with engineers, researchers, and software developers. Our goal is to provide innovative software solutions customized for clients and of original in-house design for numerical simulation and data visualization. We are the company behind the revolutionary software STKO (Scientific ToolKit for OpenSees). More than just a simple GUI, STKO features a Python scripting interface, meaning that users can customize and program the already powerful pre and postprocessors as needed, harnessing the full power of OpenSees.



CALSENS develops state-of-the-art fiber-optic sensors and designs, deploys and operates structural health monitoring (SHM) solutions to monitor bridges, buildings and vehicles (ships, airplanes, UAV), among other structures. Our services are based on constant research and innovation, creating products and services at the frontier of knowledge.

CALSENS services cover the full process of monitoring. Starting from the modelling of structural behavior and choice of control parameters, continuing with the election, design, fabrication and installation of the sensors and sensing system, until the processing, interpretation and evaluation of the data.

CALSENS has a multidisciplinary team with a high degree of expertise in the fields of civil engineering, photonic technologies, signal processing, materials engineering or computing.





Kerakoll is the international leader in the GreenBuilding sector, providing solutions that safeguard the health of both the environment and the people.

The company mission is embrace and promote GreenBuilding as the new low environmental impact approach to building and promote higher quality homes around the world through the use of eco-friendly building materials and innovative solutions.

Since 1968 – when the Group was founded in Sassuolo– Kerakoll has been pursuing a clear course of development in Italian and international markets for building materials, that has taken the company to the forefront of the GreenBuilding industry and to a level of technological supremacy famous around the globe.



S.T.A. DATA, founded in 1982 by Adriano Castagnone, civil and structural engineer since 1978, and pioneer of scientific software for structural engineering, is composed of more than 20 people, all highly qualified professionals. Our aim is to offer software for structural calculation that allow designers to face everyday work with simplicity and effectiveness.

S.T.A. DATA offers 3Muri Project, developed specifically for masonry.

In fact, it is not a generic Finite Element software adapted for masonry structures; 3Muri Project was born from the specific research for these structures and captures all the characteristics to obtain a safe and reliable calculation of historical, existing and new buildings.



IRS is a smart Engineering, Research and Development company founded by a group of engineers in 1993. IRS Structural Health Monitoring division designs, develops and integrates automated systems for mechanical and structural monitoring. Thanks to technological innovation, advanced modeling and design as well as professional production and after sales service provide a complete suite of structural health monitoring solutions. Monitoring version are both portable version for laboratory tests and one shot structural assessments and long term and in situ applications like historical sites, buildings, bridges, dams and tunnels. IRS is part of a group of companies including Measureit, with whom provides consultancy and sales of precision sensor and data acquisition systems.

SUMMARY

PRESENTED SESSIONS

Conservation of 20th c. architectural heritage	47
History of construction and building technology.....	200
Inspection methods, non-destructive techniques and laboratory testing.....	481
Interdisciplinary projects and case studies	873
Management of heritage structures and conservation strategies	1514
Numerical modeling and structural analysis.....	1675
Repair and strengthening strategies and techniques.....	2439
Resilience of historic areas to climate change and hazard events	2746
Seismic analysis and retrofit	2846
Structural health monitoring.....	3206
Vulnerability and risk analysis	3390

Contents

PRESENTED SESSIONS

Conservation of 20th c. architectural heritage

An Innovative Shell Structure in Codogno (Italy). Evaluation of Structural and Seismic Performance	47
<i>P. Brugnera, M.G. Costa and G. Mirabella Roberti</i>	
Anchorage of Reinforcement Bars in Hennebique R.C. Structures	59
<i>A. Brencich and M. Nebiacolombo</i>	
Challenges in the Reuse and Upgrade of Pier Luigi Nervi's Structures	71
<i>R. Ceravolo, G. De Lucia, E. Lenticchia, G. Miraglia, A. Quattrone, F. Tondolo, E. Matta, G. Sammartano, A. Spano and C. Chiorino</i>	
Conservation of 20th Century Concrete Heritage Structures in Cyprus: Research and Practice	82
<i>A.V. Georgiou, M.M. Hadjimichael and I. Ioannou</i>	
Conservation of Historical Reinforced Concrete Structures	94
<i>I. Bucur-Horváth and J. Virág</i>	
Decay Patterns and Damage Processes of Historic Concrete: A Survey in the Netherlands	105
<i>G. Pardo Redondo, S. Naldini and B. Lubelli</i>	
Early Concrete Structures and Post-Patented Systems: Lessons to Preserve Early 20th Historical Heritage	117
<i>I. Marcos, L. Garmendia, I. Piñero, Z. Egiluz, E. Briz and A. Gandini</i>	
Historical Buildings Made of Reinforced Concrete in Timisoara in the Beginning of the 20th Century	127
<i>R. Oprita</i>	
Reconstruction of a Masonry Windmill Tower with a Multi-Blade Wind Turbine, Steel Reservoir and Water Supply System	137
<i>P.W. Sielicki</i>	
Reinforced Concrete Floors in Historic Buildings from the Beginning and the Middle of the 20th Century - Examples of Structural Strengthening in the Process of Revitalization	144
<i>G. Dmochowski, P. Berkowski, J. Szolomicki and M. Minch</i>	
Senate Building of Canada Case Study: Seismic Rehabilitation	156
<i>L.M. Nicol</i>	
Structural Evaluation and Maintenance of Brooks Aqueduct Historic Site	168
<i>A. Rouhi and N. Shrive</i>	

Structural Evaluation of the Greenhill Mine Tipple Structure Historic Site	180
<i>A. Rouhi and N.G. Shrive</i>	
The Safety Level of Concrete Pile Foundations under Industrial Monuments	192
<i>S. Pasterkamp</i>	
History of construction and building technology	
A study of the Historical Construction Technology of Bell Towers in Cyprus	200
<i>M.L. Petrou and D.C. Charmpis</i>	
A User-Friendly Digital Tool for the Structural Assessment of Historic Domes: The Case Study of Saint Peter in Rome	211
<i>M.F. Funari, D.V. Oliveira, L.C. Silva and P.B. Lourenço</i>	
Amazonas Theater Architectural Construction and Restorations History	221
<i>M.S. Sampaio</i>	
An Example of Fit-for Purpose Use of Materials in Roman Architecture: P Temple, Side, Antalya/Turkey	233
<i>G. Kaymak Heinz</i>	
First Reinforced Concrete Building in Rijeka Port - Ferenc Pfaff's Warehouse No.17	245
<i>P. Šculac, D. Grandic and N. Palinic</i>	
Foundation Development from 1890-1942 for Long Span and High Rise Buildings at Mexico City	257
<i>P. Santa Ana, L. Santa Ana and J. Baez</i>	
From Art to Science of Construction: the Permanence of Proportional Rules in the "Strange Case" of the 19th Century Ponte Taro Bridge (Parma, Italy)	267
<i>F. Ottoni, V. Braglia, E. Coisson and L. Ferrari</i>	
Gaudí, a New Architectural Concept of Maximum Structural Efficiency: Catenary Vaults, Complex Ruled Surfaces, Branched Pillars and an Endless Innovative Strategies	279
<i>C. Salas, C. Bedoya and J.M. Adell</i>	
Geotechnical Structures in the Ancient World. The Case of the Ziggurat of Ur in Mesopotamia	291
<i>E. Kapogianni</i>	
Historical and Typological Characterization of Churches in the Historical Centre of Cusco, Peru	302
<i>K. Sovero, N. Tarque, E. Spacone, C. Mazzanti, G. Brando and C. Alfaro</i>	

Iron and Steel Construction Workshops in 19th and early 20th century Belgium: Retrieving their Oeuvre via Trade Catalogues.....	313
<i>I. Wouters and R. Wibaut</i>	
“Iron Cages”. Technical Discussions after the 1906 Valparaíso Earthquake and Reconstruction with New Techniques and Materials	325
<i>S. Maino, K. Cabezas and M. Koch</i>	
New Lightweight Structures and Historical Heavyweight Structures in Conservation	337
<i>A. Mosseri</i>	
Opus Signinum - Roman Concrete without Pulvis Puteolanis: Example of the Substructures of Diocletian’s Palace	349
<i>M.I. Šimunić Buršić</i>	
Patio as a Structural Invariant. Buildings with Patio Facing Adaptive Reuse in Barcelona	361
<i>P. Fuertes, R. Sauquet and N. Salvadó</i>	
Reconstructed Overhanging Battlements. Executive Techniques and their Vulnerability in the Stronghold of Arquata del Tronto (Italy).....	373
<i>E. Facchi, A. Grimoldi, A. G. Landi and E. Zamperini</i>	
Reinforced Concrete + Masonry: the ‘Mixed’ Structure of the Novocomum by Giuseppe Terragni.....	385
<i>A. Greppi and C. Di Biase</i>	
Safety Assessment of Existing Post-War Reinforced Concrete Bridges. The Case Study of ‘Gerber Girders’ Bridges in Italy.....	397
<i>I. Giannetti, S. Mornati, S. Coccia, F. Di Carlo and Z. Rinaldi</i>	
Structural Analysis as a Supporting Method for the Research of Medieval Brick Architecture	409
<i>P. Samol, P. Iwicki and J. Przewlocki</i>	
The “Pieve di Santa Maria” in Arezzo (Italy). From the Laser Scanner Survey to the Knowledge of the Architectural Structure	421
<i>P. Matracchi, C. Biagini, A. Sadocchi and M. Valieri</i>	
The Dome of the Temple of Diana in Baiae: Geometry, Mechanics and Architecture.....	433
<i>A. Sinopoli and D. Aita</i>	
The Spiral Staircase in the Fortified Tower of Nisida	445
<i>C. Cennamo, C. Cusano and M. Angelillo</i>	
The Structural Function of the Dutch Buttressing of the East Curtain Wall of Elmina Castle, Elmina, Ghana.....	457
<i>J. Sun, S. Tezcan and R. Perucchio</i>	
Timber Reinforcements: Local Construction Techniques in Italian Historical Buildings.....	469
<i>S. Della Torre and L. Cantini</i>	

Inspection methods, non-destructive techniques and laboratory testing

Application of Digital Close-Range Photogrammetry to Monitor Local Deformations of Architectural Monuments: A Case Study of el Mirador de Inkaraqay (Machu Picchu)	481
<i>J. Kosciuk and M. Pakowska</i>	
Axial Compression Tests on Rubble Stone Masonry Reproducing Opus Incertum of Ancient Pompeii	492
<i>F. Autiero, G. De Martino, M. Di Ludovico and A. Prota</i>	
Characterization of Cracks in Historical Buildings Using Image Processing Techniques	504
<i>P. Porcel, B. Castañeda and R. Aguilar</i>	
Characterization of Historic Mortars for Compatible Restoration: Case study of South Africa	515
<i>M. E. Loke, K. Pallav and R. Haldenwang</i>	
Comparison Between Investigation Techniques for the Evaluation of the Compressive Properties of Brick Masonry Structures	525
<i>F. Ferretti, A. Incerti and C. Mazzotti</i>	
Compressive Behaviour of Bonded Brickwork Wallettes with Various Thicknesses: Experimental and Numerical Verification	537
<i>J. Thamboo, M. Asad and T. Zahra</i>	
Data Acquisition, Management and Evaluation for Stone Conservation Projects with Digital Mapping	547
<i>S. Vetter, G. Siedler and J. Kaminsky</i>	
Dynamic Identification of Damage in Brick Masonry Walls	559
<i>S. Ivorra, D. Bru, I. Gisbert, F.J. Baeza, B. Torres and D. Camassa</i>	
Effect of Geometrical Imperfections on the Response of Dry-Joint Masonry Arches to Support Settlements	569
<i>C. Ferrero, M. Rossi, P. Roca and C. Calderini</i>	
Evaluation of the Behaviour of Lime and Cement Based Mortars Exposed at Elevated Temperatures	581
<i>V. Pachta and M. Stefanidou</i>	
Experimental Campaign on the Use of the Flat Jack Test in Cob Walls	593
<i>A. Jiménez Rios, M. Grimes and D. O'Dwyer</i>	
Experimental Investigation of Scarf Joint of 'Lightning Sign' in Bending	602
<i>A. Karolak and C. Jasieńko</i>	
Experimental Investigation on the Torsion-Shear Behaviour at the Interfaces of Interlocking Masonry Block Assemblages	614
<i>C. Casapulla, E. Mousavian, L.U. Argiento and C. Ceraldi</i>	

Fatigue Assessment of Old Riveted Railway Bridges: Laboratory Testing of a Real Bridge	626
<i>J.M. Adam, P.A. Calderón, M. Buitrago, E. Bertolesi, J.J. Moragues, S. Ivorra and B. Torres</i>	
Influence of Moisture Content on the Application of ND and MD Tests to Various Species of Timber Elements	639
<i>M.R. Valluzzi, F. Casarin, L. Scancelli, M. Drdácý, M. Kloiber and J. Hrivnák</i>	
Investigation of Rubble-Masonry Wall Construction Practice in Latium, Central Italy	651
<i>O. Al Shawa, G. De Canio, G. De Felice, S. De Santis, S. Forliti, D. Liberatore, D. Mirabile Gattia, S. Perobelli, F. Persia and L. Sorrentino</i>	
Laboratory and In-Situ Characterisation of Masonry Materials in a Large Historical Industrial Building in Barcelona	662
<i>A. Cabané, L. Pelà and P. Roca</i>	
Mechanical Characterization of Traditional Masonry in an Homogeneous Territory: Valtellina	674
<i>M. Sala, D. Foppoli and S. Della Torre</i>	
Methodologic Evolution Assessment of Large Deformations on Romanesque Masonry in Val d'Aran (XII-XIII centuries), Spain	685
<i>J. Lluís i Ginovart, M. Lopez-Piquer and C. Lluís-Teruel</i>	
Modal and Structural Identification of a Multi-Span Masonry Arch Bridge	697
<i>P. Borlenghi, A. Saisi and C. Gentile</i>	
Monitoring Deformations of a Wooden Church Tower by Laser Scanning	709
<i>L. Truong-Hong, R. Lindenbergh, P. Woudenberg, W. Gard and J.-W. Van de Kuilen</i>	
Non-Destructive Assessment of the Adhesion at the Interface Between FRCM Reinforcements and Masonry Substrates by Non-Linear Ultrasonic Technique	722
<i>A. Castellano, A. Fraddosio, T. Kundu and M.D. Piccioni</i>	
Non-Destructive Documentation Methods for Future Seismic and Damage Analysis of Modern Heritage Buildings using Contemporary Tools	734
<i>S. Rajabzadeh, M. Esponda and L. Cordero Espinosa</i>	
Non-Destructive Techniques for Characterising Earthen Structures	746
<i>E. Bernat-Maso, E. Teneva, L. Mercedes and L. Gil</i>	
Pathological and Structural Health Assessment of a Residential Building in Lota, Chile	757
<i>M. Chávez, F. Macaya, E. Nuñez and C. Oyarzo</i>	
Point-Load Test Assessment as Study of Adobe Buildings Damaged after the 2017 Puebla Earthquake	769
<i>A. Sánchez, E. M. Alonso and J. A. Bedolla</i>	

Quality and Strength Assessment of Butt Welds in Poland's Oldest Welded Railway Bridges	781
<i>B. Wichtowski and J. Holowaty</i>	
Salt Contamination of Wooden Materials: the Case of Trondheim (Norway) Warehouses	791
<i>C. Bertolin, M. Strojceki, L. De Ferri, G. Grottesi and A. M Siani</i>	
Stiffness Changes due to Static Loading of a Brick Arch.....	802
<i>J. Bayer, S. Urushadze and J. Witzany</i>	
Structural Performance and Durability Issues of Vernacular Schist Masonry	809
<i>C.E. Barroso, D.V. Oliveira and L.F. Ramos</i>	
Testing Calibration Issues in Resistance Drilling Applied to Timber Elements.....	821
<i>F. Casarin, L. Scancelli, M.R. Valluzzi and E. Bozza</i>	
The NDT Investigations Carry out at the Arudj Cathedral, Armenia.....	830
<i>S. Tonna, M. Cucchi and C. Tedeschi</i>	
The State and Condition of Historical Buildings Located on Partisan Hill in Wroclaw	842
<i>A. Hola, J. Hola, L. Sadowski and J. Szymanowski</i>	
Towards a Methodology for Use of Sonic and Ultrasonic Tests in Earthen Materials	852
<i>R. Martini, J.D. Rodriguez-Mariscal, J. Carvalho, M. Solís and H. Varum</i>	
Using the Ultrasonic Tomography Method to Study the Condition of Wooden Beams from Historical Building	863
<i>M. Zielińska and M. Rucka</i>	
Interdisciplinary projects and case studies	
A Preliminary Structural Survey of Heritage Timber Log Houses in Tonsberg, Norway	873
<i>A. Shabani, H. Hosamo, V. Plevris and M. Kioumarsis</i>	
A Protected Landmark Monument: Reinforcement, Rehabilitation, and Restoration of the Cathedral Basilica of Manizales	885
<i>O. D. Cardona and S. D. Prieto</i>	
Adaptation of a Mid-Nineteenth Century Representative University Building to Office Functions	897
<i>J. Szolomicki, M. Minch, G. Dmochowski and P. Berkowski</i>	
An Interdisciplinary Approach for the Experimental Assessments of the Seismic Safety of Artworks.....	909
<i>A. Di Martino, G. Cocuzza Avellino, E. Paterno, F. Cannizzaro, I. Calì, G. Gianfriddo, R. Valenti and N. Impollonia</i>	

Application of Geophysical Prospecting Methods for Soil Structure Characterization of the Cathedral of Santo Domingo, Dominican Republic	921
<i>J. Pérez-Cuevas, V. Flores-Sasso, E. Prieto-Vicioso, L. Ruiz-Valero and S. Sandoval</i>	
Assessment of Tunneling Induced Damage on Historical Constructions Through a Fully Coupled Structural and Geotechnical Approach.....	933
<i>A. Amorosi, M. Sangirardi, G. De Felice and S. Rampello</i>	
Automated Model Updating of a Masonry Historical Church Based on Operational Modal Analysis: the Case Study of San Giovanni in Macerata	943
<i>S. Santini, C. Baggio, E. Da Gai, V. Sabbatini and C. Sebastiani</i>	
Betang, a Traditional House of the Dayak Ngaju in Borneo Its Space Related to Structure	954
<i>M. Guntur and K. R. Kurniawan</i>	
Claudius Aqueduct in Rome - Kinematic Analyses and Empirical Experiences for the Definition of Structural Restoration Interventions	966
<i>F. De Cesaris</i>	
Comparison on Methodologies and Intervention for two Masonry Churches Affected after the 2017 Earthquake in Mexico	978
<i>M. Esponda and J. Cooke</i>	
Conservation Beyond Consolidation for Prehistoric Monuments: Finding Narratives from Archaeology to Architecture for Scottish Brochs	990
<i>C. Liu and D. Theodossopoulos</i>	
Constructive Analysis and Modelling of a Single Nave Church: a Proposal for S. Sebastiano (EN, Italy).....	1002
<i>A. Lo Faro, V. Cusmano, B. Pantò and F. Cannizzaro</i>	
Cultural Heritage Exposed to Natural Hazards: the Case Study of the Convent of San Domenico in Maiori	1014
<i>R. Landolfo, C. Tarantino, F. Portioli and L. Cascini</i>	
Design of Protective Structures for Active Archeological Sites	1026
<i>M. Petrović, I.D. Ilić, N.M. Džombić and N.D. Šekularac</i>	
Determining Qualities of Photogrammetric Models for the Use of Monitoring Movements in Stone Candis in Central Java	1038
<i>D. Grandits, L. Stampfer, E. Kodzoman, A. Setyastuti and U. Herbig</i>	
Diagnosis of an Unusual Structural Instability: the Case Study of the Cathedral of San Lorenzo in Viterbo.....	1050
<i>M. Candela, M. Eichberg and C. Tarantino</i>	
Documentation and Structural Appraisal of the Medieval Manor of Potamia, Cyprus: an Interdisciplinary Approach	1062
<i>R. Illampas, D. Myrianthefs, D. Nicolaou, V. Lysandrou, M. Philokyprou, G. Papasavvas and I. Ioannou</i>	

Effect of Slow-Moving Landslides on Churches in the Liguria Region: a Geotechnical Approach	1074
<i>L. Cambiaggi, C. Ferrero, R. Berardi, C. Calderini and R. Vecchiattini</i>	
From Reality to Point Clouds. Survey and Analysis of Sant Miquel Church of Batea (Spain)	1086
<i>A. Costa-Jover, D. Moreno Garcia, S. Coll Pla and J. Lluís i Ginovart</i>	
Historical Analysis and In-Situ Inspections of a Cultural Heritage Masonry Building	1097
<i>A. De Angelis, F. Santamato, G. Maddaloni, L. De Filippis and M.R. Pecce</i>	
Identification and Assessment of the Seismic Behaviour of Giotto's Bell Tower in Florence (Italy)	1109
<i>P. Spinelli and M. Betti</i>	
Interdisciplinary Assessment, Analysis and Diagnosis of a Historic Timber Roof Structure From the 20th Century	1122
<i>B. Isopescu, A. Keller, V. Stoian and M. Mosoarca</i>	
Non-Destructive Techniques in the Consolidation Works of the Church of S.M. of Itria in Piazza Armerina (Italy)	1133
<i>T. Basirico, S. Campione and A. Cottone</i>	
Nonlinear Structural Analysis of the Elliptical Dome of the Church in the Universidad Laboral, Gijon, Spain	1145
<i>J.J. Coz-Diaz, A. Lozano Martinez-Luengas, M. Alonso-Martinez, M.P. Garcia-Cuetos and F.P. Alvarez-Rabanal</i>	
Parameter Evaluation in Historical Construction: From Sensitivity Analysis to the Test Planning	1158
<i>A. Cali, P. Dias De Moraes and A. Do Valle</i>	
Preliminary Structural Analysis of the Western Curtain Wall of Elmina Castle, Elmina, Ghana	1170
<i>M.N. Dos Santos, S.A. Abelezele, K.A. Korslund, R.T. Cecil, S. Tezcan and R. Perucchio</i>	
Preserving Historic Bearing Structures by Prudent Integration in New Structures	1183
<i>M. Mosoarca, V. Stoian, M. Florea, M. Niculescu and M. Palade</i>	
Reconstructing the Indoor Climate of Historic Buildings	1194
<i>W. Stumpf</i>	
Renovation of 16th Century Salt House Roof (Lubań, Lower Silesia, Poland) - Case Study	1206
<i>K. Alykow and M. Napiórkowska-Alykow</i>	
Research on Architectural Form and Structural Performance of the Brick-Vault Hall Heritage in China. A case study of Yongzuo Temple	1214
<i>Q. Chun, Y. Lin and C. Zhang</i>	
Restoration Authenticity or Reality - A Case Study	1222
<i>D. Biggs</i>	

Restoration of the Queen Victoria Market Sheds E-F and J-M, Melbourne, Australia	1232
<i>J. Hettinga</i>	
Seismic Vulnerability Assessment of a 17th Century Colonial Adobe Church in the Central Valley of Chile	1244
<i>N.C. Palazzi, G. Misseri, L. Rovero and J.C. De La Llera</i>	
Slow-Moving Landslide Damage Assessment of Historic Masonry Churches: some Case-Studies in Italy	1256
<i>C. Ferrero, L. Cambiaggi, A. Fenialdi, P. Roca, R. Vecchiattini and C. Calderini</i>	
Soil Settlement and Uplift Damage to Architectural Heritage Structures in Belgium: Country-Scale Results from an InSAR-Based Analysis	1268
<i>A. Drougkas, E. Verstryngge, K. Van Balen, M. Shimoni, T. Croonenborghs, R. Hayen, P. Y. Declercq and J. Walstra</i>	
Standard Gravity and Wind Load Analysis on 103-years old Unreinforced Masonry Building	1279
<i>A. Kumar and K. Pallav</i>	
Static Analysis of a Masonry Arched and Buttressed Retaining Wall	1291
<i>D.. Dogu, C. Molins and N. Makoond</i>	
Static and Dynamic Load Test of Libeň Bridge Over Vltava River in Prague and Concept of Repair	1303
<i>P. Tej, J. Mourek and M. Blank</i>	
Structural Assessment of Cultural Heritage Buildings Using HBIM and Vibration-Based System Identification	1315
<i>A. Cali, A. Saisi and C. Gentile</i>	
Study on Causative Agents of Damage in the Costa Rican Caribbean Architecture from a Multidisciplinary Perspective	1326
<i>K. García-Baltodano, D. Porras-Alfaro and I. Hernández-Salazar</i>	
Studying a Masonry Sail Vault by Antonio da Sangallo the Elder in the Fortezza Vecchia in Livorno	1338
<i>F. Barsi, D. Aita, R. Barsotti, D. Ulivieri and S. Bennati</i>	
The Bridge Over the Adda River in Brivio: History, Full-Scale Testing and FE Modelling	1346
<i>G. Zonno and C. Gentile</i>	
The Column-Less Stair at Loretto Chapel in Santa Fe, New Mexico: Strength Analysis	1358
<i>A. Sumali</i>	
The Dar al Consul Complex in Jerusalem: Improving the Living Conditions and the Structural Capacity	1369
<i>F. Casarin, L. Di Marco, M. Mocellini, R. Sidawi, P. Dahabreh and A.K. Taweel</i>	

The Evangelical Church of Peace in Swidnica, Poland. Several Comments on its Wooden Construction and Building Technology in the Middle of the 17th Century	1381
<i>U. Schaaf</i>	
The Influence of Civil Works on Heritage Architecture, El Vergel, Cuenca - Ecuador	1393
<i>G. Barsallo, F. Cardoso, E. Sinchi, T. Rodas and M.C Achig</i>	
The Modern Impossibility of Making Art like That of the Past. Intervention Proposal for the Temple of San Juan Bautista, Tochimilico, Puebla, Mexico	1402
<i>E. Vera</i>	
The Plaster Ceilings of Buckingham Palace and Windsor Castle: Their Construction, Condition and Conservation	1409
<i>S. Brookes, K. Clark, R. Frostick, R. Ireland and L. Randall</i>	
The Restoration Interventions of “Forte Marghera” in Venice	1421
<i>F. Casarin, R. Cianchetti, T. Dalla Via, M. Meggiato and M. Mocellini</i>	
The Restoration of the Medieval Walls of San Ginesio: a Dedicated Study for the Conservation, Repair and Enhancement of an Important Military Fortification	1433
<i>M. Saracco, F. Mariano, A.A. Giuliano, L. Petetta and F. Piccinini</i>	
The Reuse of Housing Buildings in Barcelona. The Versatility of Old Constructive Structures	1445
<i>M. M`aria and X. Monteys</i>	
The Use of a Building Information Model to Support Seismic Analysis: Application to the National Palace of Sintra, Portuga	1457
<i>M. Ponte, R. Bento, R. Machete , M. Godinho, A. B. Gonalves and A. P. Falco</i>	
Thermal Behavior Assessment of Two Types of Roofs of the Dominican Vernacular Housing	1470
<i>E. Prieto-Vicioso, L. Ruiz-Valero and V. Flores-Sasso</i>	
To Reach the Light: The Monumental Byzantine Stairs of Caesarea, a Conservation and Restoration Project	1478
<i>N. Maklada, S. Hadid, D. Abuhatsira, P. Gendelman, Y. Oz and D. Siboni</i>	
Typological Characterization of Ancient Town Walls for Disaster Prevention and Mitigation. The MO.M.U. Project	1490
<i>A. De Falco, F. Giuliani, D. Ladiana, L. Rjolli, D. Bordo, F. Gaglio and M. Di Sivo</i>	
Vulnerability Assessment of Italian Rationalist Architecture: Two Case Studies	1502
<i>P. Bernardi, R. Cerioni, E. Coisson and E. Michelini</i>	

Management of heritage structures and conservation strategies

British Colonial Era's Religious Built Heritage in Yorubaland, Nigeria: Key Conservation Problematics and the State of Know-How	1514
<i>R. Sabri and O.A. Olagoke</i>	
Conservation of Architectural Complex of Manguinhos, in Rio de Janeiro, Brazil	1523
<i>B. Oliveira</i>	
Dacian Fortresses in Orastie Mountains: Management of Heritage Structures	1535
<i>G. Paşcu, A. Keller and C. Bocan</i>	
Design Criteria and Procedures for Archaeological Shelters: Towards Flexibility Thanks to Algorithmic Modelling	1547
<i>L. Sbrogiò, A. Basso, P. Borin, M.R. Valluzzi and A. Giordano</i>	
Digitization of Cultural Heritage Buildings for Preventive Conservation Purposes	1559
<i>M.G. Masciotta, L.J. Sánchez-Aparicio, S. Bishara, D.V. Oliveira, D. González-Aguilera and J. García-Alvarez</i>	
Fill-in-Glass Restoration: Exploring Issues of Compatibility for the Case of Schaesberg Castle	1571
<i>L. Barou, F. Oikonomopoulou, T. Bristogianni, F.A. Veer and R. Nijssse</i>	
Integrated Conservation Strategies in the Netherlands	1583
<i>S. Naldini, R. Van Hees and E. Van der Grijp</i>	
Modern Consolidation Methods for Catholic Church in Baroque Style from Arad Fortress, Romania	1594
<i>A.C. Ion and M. Mosoarca</i>	
Preventive Conservation for Built Heritage. Analysis of Different Models Around Europe	1606
<i>D. Stabrauskaite</i>	
Structural Typification of Heritage Buildings Using Modern Technologies for Digital Management and Visualization: Preliminary Applications in Southern Peru	1618
<i>S. Huaranga, P. Pórcel, C. Yaya, B. Castañeda and R. Aguilar</i>	
The Iscarsah Guidelines on the Analysis, Conservation and Structural Restoration of Architectural Heritage	1629
<i>P. Roca</i>	
Towards a Digital Architectural Heritage Knowledge Management Platform: Producing the HBIM Model of Bait al Naboodah in Sharjah, UAE	1641
<i>R. Sabri, S.B. Abdalla and M. Rashid</i>	

Unreinforced Masonry Structures' Seismic Improvement with F.R.C.M.: the Experience of the Vanvitellian Palazzo Murena of Perugia	1651
<i>R. Liberotti, F. Cluni and V. Gusella</i>	
Using Information Technologies for Bridge Management in Mexico's Royal Roads Built Between XVI and XVIII Century	1663
<i>A. Torres-Acosta, J. Bustamanta-Altamirano and A. Esparza-Carrillo</i>	
Numerical modeling and structural analysis	
3D FE Modeling of Multi-Span Stone Masonry Arch Bridges for the Assessment of Load Carrying Capacity: the Case of Justinian's Bridge....	1675
<i>V. G. Mentese and O. C. Celik</i>	
A Comparison Between Traditional and Modern Approaches for the Structural Modelling of Brick Masonry Barrel Vaults	1687
<i>E. Coisson, D. Ferretti and F. Pagliari</i>	
A Constitutive Model for Rubble Masonry Allowing for Spread Micro-Cracks and Localized Macro-Cracks.....	1699
<i>M. Scamardo, A. Franchi and P.G. Crespi</i>	
A Machine Learning Model for the Determination of Macro-Scale Masonry Properties based on a Virtual Laboratory at Micro-Scale.....	1712
<i>P. Kalkbrenner, L. Pelà and R. Rossi</i>	
A Macroscale Modelling Approach for Nonlinear Analysis of Masonry Arch Bridges.....	1724
<i>B. Pantò, C. Chisari, L. Macorini and B.A. Izzuddin</i>	
A Method for the Structural Analysis and Design of Arched Reinforced Masonry and/or Concrete Structures	1736
<i>D. López López, P. Roca, A. Liew, T. Van Mele and P. Block</i>	
A Novel Non-Linear Discrete Homogenization Approach for the Analysis of Double Curvature Masonry Structures.....	1746
<i>J. Scacco, G. Milani and P.B. Lourenço</i>	
A Simple and Effective Rigid Beam Model for Studying the Dynamic Behaviour of Freestanding Columns	1755
<i>D. Baraldi, G. Milani and V. Sarhosis</i>	
A Simplified Modelling Approach for the Practical Engineering Assessment of Unreinforced Masonry Structures Using Layered Shell Elements.....	1766
<i>A. Hassanieh, M. Gharib and M. King</i>	
Adaptative Pushover Analyses of a Heritage Structure: Application to a Multi-Tiered Pagoda Temple	1778
<i>Y. Endo, Y. Kondo and G. Iwanami</i>	
Advanced Tools for Fast Micro-Modelling of Masonry Structures.....	1789
<i>M. Petracca, C. Marano, G. Camata, E. Spacone and L. Pelà</i>	

Analysis and Assessment of Swedish Vaulted Masonry Structures Using Funicular Methods	1799
<i>C. Thelin and F. Höst</i>	
Applicability of FEM and Pushover Analysis to Simulate the Shaking-Table Response of a Masonry Building Model with Timber Diaphragms	1811
<i>M.P. Ciocchi, R. Marques and P.B. Lourenço</i>	
Assemblability Constraints in the Limit Analysis of 3D Masonry Interlocking Blocks	1822
<i>E. Mousavian and C. Casapulla</i>	
Assessment of Structural Damage and Evolution in Time in Historical Constructions Using Numerical Models: the Case of the Church of Saint Bassiano in Pizzighettone, Cremona	1834
<i>G. Angjeliu, G. Cardani and D. Coronelli</i>	
Calibration of a FEM Model with Complex Geometry: the Case Study of Santa Maria Maddalena Church in Ischia, Italy	1846
<i>B. Di Napoli, M.P. Ciocchi, T. Celano, P.B. Lourenço and C. Casapulla</i>	
Collaborative Use of DEM and FEM for Brick Joint Splitting in Strong Earthquake Ground Motion	1859
<i>T. Maeda, H. Tanaka, M. Shirahashi and B. Higashizawa</i>	
Combined Shear-Flexural Verification of in Plane Loaded Reinforced and Unreinforced Masonry Walls	1871
<i>A. Benedetti, M. Tarozzi and L. Benedetti</i>	
COMPAS Masonry: A Computational Framework for Practical Assessment of Unreinforced Masonry Structures	1882
<i>A. Iannuzzo, A. Dell'Endice, R. Maia Avelino, G.T.C. Kao, T. Van Mele and P. Block</i>	
Correlation Studies for the In-Plane Analysis of Masonry Walls Based on Macroscopic FE Models with Damage	1893
<i>M. Nocera, L.C. Silva, D. Addessi and P.B. Lourenço</i>	
Development of a Neural Network Embedding for Quantifying Crack Pattern Similarity in Masonry Structures	1905
<i>A. Rózsás, A. Slobbe, W. Huizinga, M. Kruithof and G. Giardina</i>	
Discrete Element Modelling of Single-Nave Churches Damaged after the 2009 Earthquake in l'Aquila, Italy	1917
<i>F. Gobbin, R. Fugger and G. De Felice</i>	
Equivalent Frame Method Combining Flexural and Shear Responses of Masonry Buildings	1928
<i>C. Marano, M. Petracca, G. Camata and E. Spacone</i>	
Estimation of the Clamping Force of Riveted Assemblies Through a Thermomechanical Modelling. Influence of Clearance and Thickness of the Connection	1940
<i>P.-J. Tisserand, S. Sire and M. Ragueneau</i>	

Excess Capacity in Historic American Reinforced Concrete Floors	1947
<i>D. Friedman</i>	
Experimental Data for the Calibration of a Non-Linear Numerical Model for Describing the Response of Masonry Constructions under Cyclic Loading	1959
<i>A. Castellano, A. Fraddosio, M.D. Piccioni, E. Ricci and E. Sacco</i>	
Fast Seismic Vulnerability Evaluation of Historical Masonry Aggregates through Local Analyses: an Adaptive NURBS-based Limit Analysis Approach	1971
<i>N. Grillanda, M. Valente, G. Milani, F. Formigoni, A. Chiozzi and A. Tralli</i>	
General Thrust Surface of the Masonry Domes	1984
<i>I. Sajtós, O. Gáspár and A. Sipos</i>	
Geometric and Structural Information for the Analysis of Historical Domes: The Case of the SS. Trinità Church in Torino	1996
<i>G. De Lucia and R. Ceravolo</i>	
In-plane Behaviour of an Iron-Framed Masonry Façade: Comparison between Different Modelling Strategies	2007
<i>T. Celano, L. Argiento, B. Pantò, F. Ceroni, C. Casapulla, I. Calì and P.B. Lourenço</i>	
Influence of Settlements and Geometrical Imperfections on the Internal Stress State of Masonry Structures	2019
<i>A. Dell'Endice, A. Iannuzzo, T. Van Mele and P. Block</i>	
Influence of Temperature on the Structural Behaviour of Masonry Buildings	2031
<i>M. Girardi, C. Padovani and D. Pellegrini</i>	
Influence of the Spatial Variability of Joints Characteristics on the Elastic Properties of Masonry	2043
<i>M.L. De Bellis, V. Sepe and M. Vasta</i>	
Inspection, Diagnosis and Modelling of Azurara Church in the North of Portugal	2054
<i>E.A. Chaves Moreno, E.T. Key, A. Uplekar, O. Pino, G. Vasconcelos, J. Ortega and E. Poletti</i>	
Investigation of the Response of a Masonry Arch Railway Bridge using Membrane Equilibrium Analysis	2066
<i>C. Olivieri, S.H. Cocking, M. Angelillo and M.J. DeJong</i>	
Investigation on the Seismic Response of a Large Monumental Complex	2076
<i>S. Caprili, I. Puncello and P. Roca</i>	
Lower-Bound Limit Analysis of Masonry Arches with Multiple Failure Sections	2088
<i>N.A. Nodargi and P. Bisegna</i>	

Minimum Thickness and Collapse Conditions of the Irregular Masonry Arch Subject to its Own Weight	2100
<i>N. Cavalagli, V. Gusella and R. Liberotti</i>	
Neomudejar Architecture and Analysis of Local Stresses of Masonry Structures: The Escuelas Aguirre Case Study	2112
<i>J. García-Muñoz, D. Mencías-Carrizosa and F. Magdalena-Layos</i>	
New Strategies to Assess the Safety of Unreinforced Masonry Structures Using Thrust Network Analysis	2124
<i>R. Maia Avelino, A. Iannuzzo, T. Van Mele and P. Block</i>	
Nonlinear Behaviour of Two-Whyte Stone Walls	2136
<i>B. Dinç-Şengönül, Y.M. Hothot, B. Doran, N. Yüzer, S. Ulukaya and D. Oktay</i>	
Novel Constitutive Modelling Approach for Shape Memory Alloys Vibration Control Devices	2146
<i>K. Wasilewski and A. Zbiciak</i>	
Numerical Analysis of Historical Reinforced Concrete Shell.....	2156
<i>P. Kněž, P. Tej and J. Kolísko</i>	
Numerical Development of a Strengthened Wall-to-Diaphragm Seismic Connection: Calibration and Application on a Building Prototype.....	2168
<i>F. Solarino, D.V. Oliveira and L. Giresini</i>	
Numerical Modelling of the Seismic Performance of Romanian Traditional Timber-Framed Buildings.....	2181
<i>F. Parisse, E. Poletti, A. Dutu and H. Rodrigues</i>	
Numerical Simulation of Traditional Timber-Masonry Buildings Subjected to Lateral Loads	2194
<i>B. Jimenez and L. Pelà</i>	
Numerical Study of Out-of-Plane Behaviour of Timber Retrofitted Masonry Prisms	2206
<i>J. A. Dauda, L.C. Silva, P.B. Lourenço and O. Iuorio</i>	
Numerical Study of Pier-Wall Connections in Typical Dutch URM Buildings	2217
<i>D. Fusco, F. Messali, J.G. Rots, D. Addessi and S. Pampanin</i>	
Safe Estimation of Minimum Thickness of Circular Masonry Arches Considering Stereotomy and Different Rotational Failure Modes.....	2229
<i>O. Gáspár, I. Sajtos and A. A. Sipos</i>	
Safety Assessment of Historic Masonry Structures by Limit Analysis and Deterministic Partial Safety Factors	2240
<i>F. Magdalena, A. Aznar, J. Antuna and J.I. Hernando</i>	
Seismic Assessment of Masonry Towers: The Case of Castellum Aquae System in Pompeii	2251
<i>M. Salvalaggio, V. Sabbatini, F. Lorenzoni, M.R. Valluzzi and H. Wenliuhan</i>	

Seismic Behaviour Analysis of Diaphragm Arches: Case Studies from Catalan Gothic Churches	2262
<i>D. Cacace, V. Corlito, M. Zizi, G. De Matteis and P. Roca</i>	
Sensitivity Analysis in the Rehabilitation of Historic Timber Structures on the Examples of Greek Catholic Churches in Polish Subcarpathia	2274
<i>K. Szepietowska and I. Lubowiecka</i>	
Simplex Algorithm for 3D Limit Analysis of Roman Groin Vaults	2282
<i>C. Baggio and S. Santini</i>	
Simulation of the Out-of-Plane Behaviour of URM Walls by Means of Discrete Macro-Element Method	2294
<i>C. Chácará, B. Pantò, F. Cannizzaro, D. Rapicavoli, I. Calìo and P.B. Lourenço</i>	
Stochastic Micro-Modelling of Historic Masonry	2306
<i>J. Adamek and P. Kabele</i>	
Structural Analysis of Historical Constructions by Graphic Methodologies based on Funicular and Projective Geometry	2318
<i>J. Suárez, T. Boothby and J. A. González</i>	
Structural Assessment of the Seismic Behavior of the Dome of the Taj Mahal	2330
<i>S. Rihal, B. Koh, A. Mehrotra and J. Edmisten</i>	
Structural Evaluation of Typical Historical Masonry Vaults of Cagliari: Sensitivity to Bricks Arrangements	2342
<i>A. Cazzani, N. Grillanda, G. Milani, V. Pintus and E. Reccia</i>	
Structural Modelling and Numerical Analysis of the Palace of Sports of Mexico City	2354
<i>H. Badillo-Almaraz, A. Orduña, S.G. De La Rosa, G.A. González and G.M. Roeder</i>	
Structural Performance Evaluation of Column-Nuki Connection in Traditional Japanese Wooden Buildings	2366
<i>S. Murai and M. Miyamoto</i>	
Study on Rigid Homogenization Method and Model of Masonry under Different Bricklaying Methods Based on Regular Tessellation Theory	2378
<i>Y. Chunxia, C. Shu, L. Chenyi and Z. Nan</i>	
Study on Seismic Performance Evaluation of Modern Wooden School Buildings in Japan	2390
<i>M. Miyamoto</i>	
The Influence of the Passive Earth Pressure and other Factors on the Stability of the Underground Masonry Vaults of the Paris Metro	2400
<i>O. Moreno Regan, E. Bourgeois, J. F. Douroux and A. Desbordes</i>	

The Safety of Masonry Arches Subject to Vertical and Horizontal Forces. A Numerical Method Based on the Thrust Line Closest to the Geometrical Axis	2413
<i>S. Galassi and G. Tempesta</i>	
The Unbuilt Musmeci Parabolic Cross Vault Reinvented as a Dry-Masonry Structure	2425
<i>C. Intrigila, N.A. Nodargi and P. Bisegna</i>	
Repair and strengthening strategies and techniques	
A New Method for Assessing Compatibility of Consolidation Procedures with Conservation Principles: Intervention Quality Index (IQI)	2439
<i>N.C. Palazzi, G. Misseri, C. Sandoval, U. Tonietti, J.C. De La Llera and L. Rovero</i>	
Characterization of FRCM- and FRP-Masonry Bond Behavior	2451
<i>C. Gentilini, C. Carloni, R. Santoro and E. Franzoni</i>	
Cost-Effective Implementation of Nitinol to Improve the Seismic Performance of an Unreinforced Masonry Building	2458
<i>T.F. Paret and J.M. Rautenberg</i>	
Cyclic Tests on Masonry Vaults Strengthened Through Composite Reinforced Mortar	2470
<i>N. Gattesco and I. Boem</i>	
Evaluation of Performance of Matured Hydraulic Grouts: Strength Development, Microstructural Characteristics and Durability Issues	2480
<i>A. Miltiadou-Fezans, M Delagrammatikas, A. Kalagri and P. Vassiliou</i>	
Experimental and Numerical Analyses on Sandstone Elements Obtained by 3D Printing	2492
<i>C. Scuro, S. Tiberti, S. Porzio, R.S. Olivito and G. Milani</i>	
Experimental and Numerical Analysis of a FRCM Reinforced Parabolic Tuff Barrel Vault	2504
<i>A. Castellano, J. Scacco, A. Fraddosio, G. Milani and M.D. Piccioni</i>	
Experimental Assessment of Cyclic Shear Response of Brick Masonry Walls Retrofitted with TRM	2516
<i>L. Garcia-Ramonda, L. Pelà, P. Roca and G. Camata</i>	
Experimental Investigation of the Bond between Glass Textile Reinforced Mortar (GTRM) and Masonry Substrate: the Effect of Textile Impregnation	2528
<i>P.D. Askouni and C.G. Papanicolaou</i>	
Experimental Study on the Shear Behavior of FRCM Strengthened Masonry Panels	2540
<i>F. Ferretti, A. Incerti and C. Mazzotti</i>	
Experimental Tests on FRCM and FE Modelling for the Heritage Structure's Reuse	2552
<i>R. Liberotti, N. Cavalagli and V. Gusella</i>	

Fibre Reinforced Geopolymers as Inorganic Strengthening Composites for Masonry Structures	2564
<i>E. Garbin, M. Panizza, S. Tamburini, M. Natali and G. Artioli</i>	
Flexural Resistance of Masonry Wall Retrofitted with Timber Panels under Out-Of-Plane Loading	2576
<i>O. Iuorio, J. A. Dauda and P.B. Lourenço</i>	
From the Cure of the Simple Structural Analysis to the Control of the Final Technological Quality - The Conservation of "Santa Maria Degli Angeli Orphanage" in Castelgrande (Potenza, Italy)	2586
<i>F.P.R. Marino, G. Auletta, F. Baldantoni, F.C. Ponzo and F. Lembo</i>	
Historical Timber Structures in Adana-Tepebag Settlement and Consolidation Approach with Modern Timber Prefabricated Systems	2600
<i>K. Apak</i>	
Numerical Modelling of Masonry Arches Strengthened with SFRM	2612
<i>S. Caddemi, I. Calì, F. Cannizzaro, D. Rapicavoli, N. Simoncello, P. Zampieri, J. Gonzalez-Libreros and C. Pellegrino</i>	
Out-of-Plane Behaviour of Tuff and Brick Masonry Walls Strengthened with FRCM Composite Materials	2620
<i>A. Bellini, A. Incerti, A. Nanni and C. Mazzotti</i>	
Overview of the Mechanical Properties of Steel Reinforced Grout Systems for Structural Retrofitting	2632
<i>F. Roscini, S. De Santis, P. Meriggi and G. De Felice</i>	
Performance Assessment of Basalt FRCM for the Confinement of Clay Brick Masonry Cylinders	2642
<i>J. D'Anna, G. Amato, J.F. Chen, G. Minafò and L. La Mendola</i>	
Performance of Unreinforced Masonry Strengthened with Bed Joint Reinforced Repointing	2652
<i>L. Licciardello, J.G. Rots and R. Esposito</i>	
Reinforcement and Consolidation of Masonry Structures. Successful Cases Implemented: From the Study to the Execution Phase	2664
<i>J. Dobon and M.A. Soria</i>	
Repair Connection with Wooden Wedged Dowels: Preliminary Experimental Laboratory Tests and FEM Model for the Description of the Mechanical Behavior	2673
<i>E. Perria, S. Siegert, X. Li and M. Sieder</i>	
Stabilization and Consolidation of Historical Multi-Leaf Masonry	2687
<i>J. Witzany, J. Brožovský, T. Čejka, J. Kubát and R. Zigler</i>	
Static Test on Full Scale Rammed Earth Building with Mesh-Wrap Retrofitting Strategy	2696
<i>K.C. Shrestha, T. Aoki, M. Miyamoto, N. Takahashi, J. Zhang, P. Wangmo, N. Yuasa, S. Shin, P. Pema and K. Tenzin</i>	

Structural Restoration and Re-Use of the Historic Coal Mine Tower	2708
<i>D. Andic, M. Horvat and J. Pojatina</i>	
The CLT Panels in Structural Restoration: Characteristics and Technical Regulations	2718
<i>G. Frunzio, L. Di Gennaro , L. Massaro and F. D'Angelo</i>	
Treatment for Rising Damp and Natural Hydrodynamic Equilibrium in Masonry Walls.....	2729
<i>J. Dobon and M.A. Soria</i>	
TRM-Strengthened Timbrel Cross Vaults Subjected to Vertical Settlements	2737
<i>P.A. Calderón, E. Bertolesi, M. Buitrago, J.J. Moragues and J.M. Adam</i>	
Resilience of historic areas to climate change and hazard events	
A Framework for the Detailed Flood Vulnerability Modelling of Built Cultural Heritage	2746
<i>R. Figueiredo, X. Romão and E. Paupério</i>	
Assessing the Impact of Seismic Risk Mitigation at the Urban Scale on Community Resilience and Housing Recovery	2757
<i>A. Basaglia, A. Aprile, E. Spacone and L. Pelà</i>	
Fire Prevention in Ottoman and Habsburg Building Codes for Bosnia and their Application in Travnik.....	2768
<i>C. Jaeger-Klein, A. Bajramovic and L. Stampfer</i>	
Landslide Hazard Affecting Historical Buildings: Santa Scolastica Monastery in Subiaco	2780
<i>M. Sangirardi, A. Amorosi and G. De Felice</i>	
Post-Earthquake Reconstruction of the Historic City Center of l'Aquila: A Proposal Concerning the Rubble Transportation Problem	2790
<i>S. Di Marco and M.A. Bragadin</i>	
Post-Quake Small Italian Historical Centres: Urban Resilience between Rhetorics and Reality. The Case Study of Nocera Umbra after the 1997 Umbria-Marche Earthquakes	2802
<i>E. Cianci, C. Fontana, G. Occhipinti and G. Romagnoli</i>	
Preliminary Approach for a Prototype of Sustainable Antiseismic Dwelling in Nepal Based on the Historic Vernacular Tradition.....	2814
<i>F. Vegas López-Manzanares, C. Mileto, W. Pisarra and F. Trizio</i>	
Resilience and Vulnerability of Historical Centres: the Case of the District of Camerino in the Marche Region	2824
<i>E. Petrucci, L. Barchetta and D. Lapucci</i>	
Resilience of Historic Residential Areas Subjected to Natural Disasters.....	2836
<i>M. Drdácý, R. Cacciotti and T. Drdácý</i>	

Seismic analysis and retrofit

- An Integrated Modeling Approach that Combines Elastic Amplification and Rocking Analysis for Seismic Assessment of a Masonry Tower** 2846
A. Mehrotra, A. Liew, P. Block and M.J. DeJong
- Assessment of the Seismic Retrofitting of a Historical Masonry Mosque by means of Nonlinear Dynamic Analysis** 2858
A. Aşıkoğlu, L.C. Silva, O. Avşar and P.B. Lourenço
- Comparison of Two Different Approaches for the Seismic Evaluation of the Bonet Building of the National Palace of Sintra, Portugal**..... 2870
M. Ponte, M. Malcata and R. Bento
- Damages Patterns in Historical Temples of Puebla, Morelos and Oaxaca after September 2017 Mexico Earthquakes** 2882
M. Chávez, F. Peña, N. García and D. Durán
- Design of Shake Table Tests of Multi-Leaf Masonry Walls Before and After Retrofitting** 2894
S. De Santis, O. Al Shawa, G. De Canio, S. Forliti, D. Liberatore, P. Meriggi, I. Roselli, L. Sorrentino and G. De Felice
- Effect of Historic Timber Roof Structures on the Structural Behaviour of Masonry Buildings during Seismic Events** 2902
A.I. Keller and M. Mosoarca
- Evolution of Lateral Design in the United States** 2914
N.A. Hicks and E.P. Meade
- Extradados Strengthening of Single-Leaf Vaults Against Seismic Actions** 2926
S. Cominelli, C. Passoni, A. Marini, A. Belleri and E. Giuriani
- Inadequate Cases of Intervention in Architectural Heritage Buildings in Mexico after the September 2017 Earthquakes**..... 2938
F. Peña and M. Chávez
- Macroelement Numerical Simulation of the Seismic Response of a Timber-Retrofitted Masonry Pier**..... 2946
M. Miglietta, N. Damiani, S. Bracchi, G. Guerrini, F. Graziotti and A. Penna
- Mechanical Characterization of Energy Dissipation Devices in Retrofit Solution of Reinforced Concrete Frames Coupled with Solid Wood Panels** 2958
C. Tardo, F. Boggian, M. Hatletveit, E. Marino, G. Margani and R. Tomasi
- Numerical Investigation of the Retrofitting Interventions of the San Benedetto Church Complex in Ferrara (Italy) from a Seismic Vulnerability Perspective** 2970
R. Shehu

Numerical Investigations for Assessing the Seismic Performance of Multi-Tiered Nepalese Temples	2981
<i>M. Pejatovic, V. Sarhosis and G. Milani</i>	
Numerical Simulation on Seismic Performance of Retrofitted Masonry Wall in Historical Buildings Damaged in Earthquake	2993
<i>B. Wu, J. Dai and W. Bai</i>	
Repair and Retrofit of a Roman Bridge in Turkey	3005
<i>H. Sesigur and M. Alaboz</i>	
Seismic Assessment and Strengthening Interventions of Atop Single-Block Rocking Elements in Monumental Buildings: the Case Study of the San Felice sul Panaro Fortress	3016
<i>S. Degli Abbatì, S. Cattari, S. Lagomarsino and D. Ottonelli</i>	
Seismic Assessment of Dutch URM Buildings According to NPR9998:2018 Code with an Equivalent-Frame Approach	3028
<i>S. Bracchi, F. Graziotti, F. Messali and A. Penna</i>	
Seismic Assessment of Heritage Buildings in Bulgaria	3040
<i>M.D. Traykova and A.V. Traykov</i>	
Seismic Behaviour of La Merced Temple in Morelia, Mexico	3052
<i>L. Mejia, G. Martinez, B. Olmos and J.M. Jara</i>	
Seismic Damage Mechanisms for Churches and Damage Sequence: Considerations from a Case Study	3065
<i>M.A. Parisi, Y. Anzilotti, G.I. Fuentes Rivera, G. Sferrazza Papa and S. Barbo</i>	
Seismic Fragility Analyses of the Cabinet Stored Artefacts with and without Damping Method	3077
<i>W. Bai, J. Dai and Y. Yang</i>	
Seismic Performance Evaluation of Box-Shaped Wall Structures Built with Thick Earthen Walls	3087
<i>H. Yokouchi and Y. Ohashi</i>	
Seismic Performance of Masonry Cross Vaults through Shaking Table Testing on a Scaled Model	3098
<i>N. Bianchini, N. Mendes, P. Candeias, M. Rossi, C. Calderini, P.B. Lourenço and A. Campos Costa</i>	
Seismic Response of Hagia Sophia Church in Thessaloniki Including Soil-Foundation-Structure Interaction	3109
<i>A. Chounta, C. Malakoudi, C. Petridis and D. Pitilakis</i>	
Seismic Retrofitting of Historical Masonry Heritage Structures: A Case Study of an Adobe Masonry Building in Lima, Peru	3121
<i>T. Martins, J. García, A. Ferrández, N. Tarque and J. Fernández</i>	
Seismic Stability Analysis of Inca Earthen Walls	3133
<i>A. Torres, M. Blondet and S. Santa Cruz</i>	

Simplified Method for the Lateral Strengthening of Earthen Churches ... 3145
R. Enciso, M. Noel and R. Aguilar

**Structural Analysis of a Restored Byzantine Monastery:
Effectiveness of the Interventions** 3156
P. Condoleo and A. Taliercio

**Structural Assessment of the 13th Century Great Mosque and
Hospital of Divrigi: A World Heritage Listed Structure** 3169
C. Demir, O.F. Halici, A.N. Sanver, M. Comert, F. Kuran, N. Berlucchi, A. Hurata and A. Ilki

**The Floor Stiffness Effect on Vulnerability Assessments and
Intervention Designs of Historic Buildings: the Case Study of
the "Procuratie Vecchie" in Venice, Italy** 3181
I. Rocca, L. Berto, S. Bellin, B.F. Dongmo, A. Saetta and R. Vitaliani

**Understanding Traditional Anti-Seismic Strategies Beyond
Their Disappearance and Distortions: Yazd Qajar Architecture
Case Study** 3193
E. Crété, S. Yadav, N. Farahza, L. Arleo, M. Hajmirbaba, Y. Sieffert and P. Garnier

Structural health monitoring

**Assessment and Monitoring of Historical Timber Construction:
Available Tools to Support Decision-Making Processes** 3206
M. Riggio

**Continuous Structural Monitoring of Adobe Buildings:
Summary of a Three Years Experience in Peru** 3218
G. Zonno, R. Aguilar, R. Boroschek and P.B. Lourenço

**Data Analysis Using ARX Models Applied to Static Structural
Health Monitoring of the Monastery of Sant Cugat** 3228
N. Makoond, L. Pelà, C. Molins and P. Roca

Development of a Wireless Acceleration Measurement System 3240
T. Yamasaki, K. Ota, M. Miyamoto, Y. Amano, M. Okada and T. Kido

**Dynamic Identification of the So-Called Temple of Minerva Medica:
Comparison of Different Instrumentations and Methods for
Mutual Validation of the Results** 3252
C. Baggio, V. Sabbatini, S. Santini, C. Sebastiani, V. Fioriti, I. Roselli, A. Colucci, F. Saitta and S. Forliti

**Health Monitoring Tests of Heritage Structures:
Application of MEMS Accelerometers to Two Multi Tier Pagodas** 3264
Y. Endo and Y. Niitsu

**Long-Term Structural Health Monitoring of the Fortezza Fortress:
Application of Damage Detection Techniques on Existing Cracks** 3272
M. Drygiannakis, G. Vlachakis and A. Tzigounaki

Monitoring of Indoor Environmental Conditions of the Kvernes (Norway) Stave Church	3284
<i>C. Bertolin, L. De Ferri and T.M. Olstad</i>	
Multi-Modal Analysis of Vibration and Meteorological Data for Structures on the World Heritage Site “Battleship Island”	3296
<i>N. Kurata, K. Takai, A. Tomioka, T. Daigo, S. Saruwatari and T. Hamamoto</i>	
One-year Static Monitoring of the Milan Cathedral	3305
<i>A. Saisi, A. Ruccolo and C. Gentile</i>	
Proposal for a Time-Dependent Dynamic Identification Algorithm for Structural Health Monitoring	3317
<i>M.F. Hormazábal, M.G. Masciotta and D.V. Oliveira</i>	
Quantification of the Structural Response of Historical Constructions: Investigation of the Strain Variation at the Acropolis Circuit Wall	3329
<i>E. Kapogianni, P. Psarropoulos and M. Sakellariou</i>	
Real-Time Structural Monitoring of Bibi-Khanum in Samarkand (Uzbekistan) Combined with Subsequent Laser Scans	3339
<i>S.M. Takhirov, I. Aripov and D. Matrasulov</i>	
Structural Health Monitoring of a Historic Church: Theory and Practice of Diagnostic Approaches Used to Control Risks and Costs	3349
<i>T. Morrison and S. Burrill</i>	
Structural Health Monitoring of the Juma Mosque in Itchan Kala in Khiva (Uzbekistan): Laser Scanning Combined with Numerical Modelling	3361
<i>S. Takhirov and B. Rakhmanov</i>	
Structural Monitoring in the “Santa Maria de la Asunción” Cathedral of Chilpancingo, Guerrero, Mexico; through Topogeodesic-Photogrammetric Surveying and Ambient Vibration. A Methodological Proposal	3371
<i>S. Sánchez Tizapa, R. Aurelio Felicito, R. Vázquez Jiménez, J. L. Carranza Bello and R. Arroyo Matus</i>	
The Influence of External Climate on Church Internal Microclimate	3381
<i>L. Balik, L. Kudrnacova and K. Nedvedova</i>	
Vulnerability and risk analysis	
A Comparison Between Empirical Procedures for the Definition of Vulnerability Classes of Masonry Buildings: Application to Five Historical Centres Struck by 2016 Central Italy Earthquake	3390
<i>Y. Saretta, L. Sbrogiò and M.R. Valluzzi</i>	
A QGIS Plugin for the Seismic Vulnerability Assessment of Urban Centers: Application to the City of Popoli in Abruzzo (Italy)	3402
<i>A. Gonzalez, A. Basaglia, E. Spacone and G. Brando</i>	

Assessment of Seismic Fragility of Historical Buildings at the Urban Scale by Typological-Mechanical Approaches: the Case Study of Foggia	3414
<i>V. Leggieri, S. Ruggieri and G. Uva</i>	
Criteria for the Vulnerability Analysis of Structural Aggregates in Historical Centers	3426
<i>S. Tonna, M. Boriani, M.C. Giamb Bruno and C. Chesi</i>	
Decision Support System for Vulnerability Assessment of Masonry Churches Including Architectural and Artistic Assets	3438
<i>V. Sangiorgio, G. Uva and J.M. Adam</i>	
Development of a Fire Damage Index for Immovable Cultural Heritage	3450
<i>L.G. Salazar, E. Paupério and X. Romão</i>	
Evaluation of Invasive Retrofitting Interventions on an Unreinforced Masonry Heritage Building	3462
<i>A. Scupin, R. Vacareanu and F. Pavel</i>	
Kinematic Approach for Seismic Vulnerability Assessment of Masonry Churches	3474
<i>V. Corlito, G. De Matteis and P. Roca</i>	
Managing Natural Disasters in Historic Areas: a Novel Holistic Seismic Risk Assessment Method Applied to a Relevant Case Study	3486
<i>E. Quagliarini, G. Bernardini and M. Lucesoli</i>	
Risk Assessment Methodologies to Safeguard Historic Urban Areas from the Effects of Climate Change	3498
<i>L. Quesada-Ganuza, L. Garmendia, E. Rojí, I. Álvarez, E. Briz and M. Olazabal</i>	
Risk Management and Built Heritage: Towards a Systematic Approach	3510
<i>A. Konsta and S. Della Torre</i>	
Seismic Damage Scenarios Induced by Site Effects of Masonry Clustered Buildings: a South Italy Case Study	3522
<i>A. Formisano and N. Chieffo</i>	
Seismic Vulnerability Assessment Method for Vernacular Architecture Considering Uncertainty	3534
<i>J. Ortega, S. Saloustros and P. Roca</i>	
Seismic Vulnerability Assessment Methodology for Historical Buildings with Cultural Value	3546
<i>E. Onescu, I. Onescu and M. Mosoarca</i>	
Seismic Vulnerability Assessment of a Historic Brick Masonry Building by Fragility Functions	3558
<i>K. Demirlioglu and S. Soyoz</i>	

Seismic Vulnerability Assessment of Representative Building Typologies from Barcelona’s Eixample District	3569
<i>S. Dimovska, S. Saloustros, L. Pelà and P. Roca</i>	
Seismic Vulnerability Assessment of Romanian Historical Building under Near-Source Earthquake	3581
<i>N. Chieffo, M. Mosoarca, A. Formisano and P.B. Lourenço</i>	
Seismic Vulnerability of Heritage Churches in Québec: the Néo-Roman Typology	3593
<i>G. Sferrazza Papa, M-J. Nollet and M.A. Parisi</i>	
Simplified Seismic Vulnerability Assessment of Medieval Masonry Churches	3605
<i>V. Corlito, M. Zizi and G. De Matteis</i>	
The Assessment and Reduction of Seismic Risk: Towards a System of Knowledge for Archaeological Pre-Existences	3617
<i>E. Montenegro</i>	
The Damage Survey of Cultural Built heritage Between Simplified Procedures and Needs for Implementation: the Case Study of Emilia-Romagna Cemeteries	3629
<i>V. Vona and M. Zuppioli</i>	
Typological Classification and Observed Damage Patterns of Masonry Churches After the 2016 Central Italy Earthquake	3641
<i>G. Cianchino, C. De Matteis and G. Brando</i>	
Vulnerability Assessment of Dwellings in the Historic Center of Cusco (Peru)	3652
<i>G. Brando, G. Cocco, C. Mazzanti, M. Peruch, E. Spacone, C. Alfaro, K. Sovero and N. Tarque</i>	
Vulnerability Assessment of Italian Unreinforced Masonry Churches Using Multi-Linear Regression Models	3661
<i>A. Marotta, D. Liberatore and L. Sorrentino</i>	

PRESENTED SESSIONS

CHALLENGES IN THE REUSE AND UPGRADE OF PIER LUIGI NERVI'S STRUCTURES

R. CERAVOLO¹, G. DE LUCIA¹, E. LENTICCHIA^{1*}, G. MIRAGLIA¹,
A. QUATTRONE¹, F. TONDOLO¹, E. MATTA², G. SAMMARTANO², A. SPANÒ²,
C. CHIORINO³, G. BRUSCHI⁴, P. FACCIO⁴, A. NANNI⁵

¹ Department of Structural, Geotechnical and Building Engineering,
Politecnico di Torino, Turin, Italy.

e-mail: rosario.ceravolo@polito.it; giulia.delucia@polito.it; *erica.lenticchia@polito.it;
gaetano.miraglia@polito.it; antonino.quattrone@polito.it; francesco.tondolo@polito.it

² Department of Architecture and Design
Politecnico di Torino, Turin, Italy.

e-mail: emiliano.matta@polito.it; giulia.sammartano@polito.it; antonia.spano@polito.it

³ Pier Luigi Nervi Project Association, Brussel, Belgium
e-mail: cristiana.chiorino@gmail.com

⁴ Dipartimento di Architettura, Costruzione e Conservazione
IUAV University of Venice, Venice, Italy.
e-mail: faccio@iuav.it

⁵ Civil, Architectural and Environmental Engineering Department
University of Miami, Miami, Florida, USA.
e-mail: nanni@miami.edu

Keywords: Historical Structure, 20th century architectural heritage, Conservation Plan

Abstract. *The paper presents the overall objectives of a funded research program for the development of a Conservation Plan (CP) for the two halls by Pier Luigi Nervi of the Turin Exhibition Center. The Turin Exhibition Center was conceived immediately after the Second World War to host primarily the annual Automobile Show, in connection with the presence in Turin of the FIAT motor company. The two main pavilions of the Center (Halls B and C) are outstanding examples of a pioneering use, of new advanced methods in reinforced concrete construction, combining innovative prefabrication procedures and the re-invention by Nervi of ferrocement, used to form extremely thin elements. The CP is expected to push and contribute to the preservation of the halls designed and built by Nervi, with special emphasis on structural and seismic vulnerability aspects, also due to concerns raised on the durability of concrete materials and technologies. Re-using these buildings entails the challenge to guarantee new extended service life to concrete structures built many decades ago and faces the need for a seismic assessment of these structures, in compliance to recent Italian standards.*

1 INTRODUCTION

The present work is part of a topical line regarding the analysis and structural diagnosis aimed at the conservation of 20th century architectural heritage. A heritage of great importance which is however characterized by several problems, first of all the scarce recognition of their historical-documental value. In fact, the preservation of 20th century architecture has fully entered the wider disciplinary of conservation. However, in practice, this cultural awareness clashes with the difficulties involved in adapting recent buildings to current building regulations. Moreover, many of the characteristics of modern architecture - such as the use of advanced construction methods and materials and the development of new building types and forms - challenge traditional conservation approaches and raise new methodological issues. In fact, the assessment of the twentieth century architectures poses new problems in terms of material preservation, structural analysis and reuse [1] [2]. Addressing these challenges will require convergent contributions from experts of different fields. From the point of view of their seismic improvement, 20th century buildings present specific issues, connected to the materials and techniques used for the construction, as well as to the complex and innovative spatiality; the continuous experimentations in all these areas have been among the characteristic features of architectural and engineering research of the past century [3]. For these reasons, in view of a restoration and re-functionalization of these buildings, it is a priority to carry out a careful evaluation of the structural performances, both as regards the level of safety in static conditions and from the point of view of seismic behavior. Experimental activities, including dynamic tests, are part of those operations aimed at identifying the structural characteristics, determining the state of health of the structure and predicting the response to seismic actions.

One of the reasons of the current abandonment of the Turin Exhibition Center, as well as of other Italian Nervi's buildings (e.g. Palazzo del Lavoro, Stadio Flaminio), is the lack of virtuous examples for guiding the renovation and/or reuse projects of the Modern architectural heritage in Italy. The contribution will address the issues regarding the preservation of modern heritage architecture as seen from the perspective of a country exposed to seismic risk. The paper presents the overall objectives of a funded research program for the development of a Conservation Plan (CP) for the two halls by Pier Luigi Nervi of the Turin Exhibition Center.

2 THE CASE STUDY

The monumental complex of Turin Exhibition Center represents a milestone in the history of modern engineering and architecture. The complex was designed and built between the 1948 and 1950 by Pier Luigi Nervi, one of the greatest and most inventive structural engineers of the 20th century [4] [5], as a public space to host primarily the annual Automobile Show, in connection with the presence in Turin of the FIAT motor company. In the construction of both halls of Turin Exhibition Centre, Nervi used new construction procedures that he studied for some years before this project. In fact, he had already successfully used these procedures with his engineering firm Nervi and Bartoli, though on smaller experimental buildings, such as the small storehouse in the Magliana area in Rome (1946) [6], the wharf Conte Trossi in San Michele di Pagana (1947) and the ceiling of the pavilion at the Milan Fair (1947) [7]. Reference to this celebrated and iconic masterpiece, as one of the most skillful examples of structural art, is very frequent in the literature on contemporary architecture. This combined use of two

different technologies for the construction of large concrete shells, would become one of the distinctive trait of Nervi's work.



Figure 1: Turin Exhibition Center, Pavilions by Pier Luigi Nervi: Hall B (left and center) and Hall C (right).

The roofing systems, in particular, are outstanding examples of a pioneering use, at the intersection between inspiration and technique, of new advanced methods in reinforced concrete construction, combining extensive use of innovative prefabrication procedures and reinvention by Nervi of ferrocement, as an extremely malleable building material. As in the large majority of his works, Nervi was both the designer and, through its construction company, the builder of the Exhibition Center. In the fifties Nervi will be asked to design a second pavilion (Hall C) and to enlarge the Hall B. Figure 1 shows the interiors of the two halls built by Nervi. Shaped like a fascinating modern cathedral, Hall B (1947-1948) consists of an imposing wide nave covered by a cylindrical barrel vault, and an elegant apse with ribbed hemispherical dome. For the realization of the arches of the vault, Nervi conceived wave-like prefabricated ferrocement elements joined by cast on site reinforced concrete ribs. Stylish fans connect the arches to the inclined columns. The apsidal semi-dome was built using lozenge-shaped ferrocement tiles connected by reinforced concrete cast in the lateral ribs and on their tops. Hall C (1950) is characterized by a captivating ribbed vault, constructed with the same system of ferrocement tiles and resting on four sculpturally shaped inclined arches. A clear proof on how significant the design and construction of both pavilions had been in the growth as a builder for Pier Luigi Nervi, is the fact that after the completion of both halls he immediately registered the patents of the solutions he employed during the construction site. In fact, Nervi registered various patents: patent no. 445781 in Rome on August 26th 1948, entitled "Ferrocement wave" and patent no. 465636 in on 19 May 1950, entitled "Building procedure for creating flat or curved load-resisting surfaces consisting of grids of reinforced concrete ribbing, possibly finished with connecting concrete slabs between the ribs" [8]. These patents would be adopted by Pier Luigi Nervi in the following decades until becoming a typical feature of the globally recognized Nervi's style [8] [9]. Moreover the experimentation of this new solutions was accompanied by the structural prefabrication, that Nervi already developed during the construction of a series of hangars for the Italian Air Force in the late 30s. It is important to note that Nervi's prefabrication did not concern factory-made standard construction elements. In fact, in each building he simply used prefab elements, made onsite. Nervi's concept of

structural prefabrication meant that structures had to be broken down and each element had to be prepared on the ground (Figure 2). Every element had to be small enough and light enough to be lifted and easily assembled. Despite its misleading name (prefabrication) it is just a very old technique, in continuity with the tradition of stereometry.



Figure 2: The onsite prefabrication procedure of the undulated ferrocement elements of Hall B and their positioning.

The building is protected with a Landscape protection by the City Masterplan and since 2018 is listed in the National Heritage by the Ministry of Culture (*Codice dei beni culturali e del paesaggio*, D. Lgs. 42/2004) because it's a public building of 70 years old.

Despite its remarkable historical and architectural relevance, the Turin Exhibition Centre has been abandoned for a long time and the lack of maintenance is starting to induce serious preservation problems. In fact, after the transfer in the late 1980s of the Automobile Show to another location, the Center was used for sporadic exhibitions and events and progressive abandon followed. Even more so, these buildings were designed and built with no, or very limited, seismic provisions, due to the lack of technical standards at the time. The CP will issue guidelines to reconcile structural requirements and conservation criteria.

3 THE CONSERVATION PLAN

The conservation of the architectural heritage of the modern movement is the latest and perhaps one of the most contentious frontiers in the field of architectural preservation. Long-standing prejudices and a persistent public lethargy often overcome objective analysis when Modern buildings are faced with demolition or disfiguring renovations [2] [3].

The first act in defining approaches related to the preservation of modern architecture is aimed at recognizing the object as a monument, document, or material testimony, having the value of civilization, which implies a conservative need or a slowing down of the processes of degradation. Criteria, principles and postulates of the modern restoration critically and scientifically understood (distinctiveness, minimal intervention, potential reversibility, respect for authenticity and ancient matter, physical-chemical compatibility of additions, recognition under the double aesthetic and historical requirement of the work) correspond to those developed for the now shared actions of restoration of monuments. These statements find a first

difficulty in the specific disciplines related to the conservation project, but will be overcome thanks to a holistic approach that focuses not on individual scientific contributions but the object as a central element of research in the unity of architecture and structure.

Also the ICOMOS20 groups states that “*There is also some confusion about the basic principles of conservation that should be applied to twentieth-century sites and places*” [10]. The difficulty, or even lack, of communication between architects and engineers has always been one of the main obstacles in the analysis and conservation of the architectural heritage. In fact international guidelines states that the conservation, reinforcement and restoration of the architectural heritage require a multidisciplinary approach. A typical example of interdisciplinary approach is the interaction that has to occur between historical research and structural diagnosis: historical research can discover particular phenomena involving structural behavior whilst historical questions may be answered by considering the structural behavior.

3.1 Scope and challenges of the project

More generally, the research project may be ascribed to the structural assessment and retrofit of 20th century architectural heritage, characterized by a complex 3D structural design. The service life of civil and Cultural Heritage (CH) concrete spatial structures is typically thought to range from 10 to 200 years, but in practice, the service environment plays a pivotal role in sustained durability. We address the challenge of monitoring, conserving and rehabilitating 20th century concrete CH because: concrete has become a 20th century emblem; consequently, specific studies are needed that contribute to the successful reuse of modern concrete built heritage. More specifically, large spatial concrete structures, conceived by 20th century European architects and engineers, represent a powerful common world background. Moreover, such structures are plagued by significant deterioration and most of them are in urgent need of retrofitting and/or radical refurbishment. There is a need to bring some of these buildings back to life, while respecting the spirit of their original characters, through new technologies for long-term conservation that can maintain an adequate level of structural and seismic performance. Achieving this goal would produce substantial economic impacts through activities such as tourism, restoration, maintenance, and cultural industry.

The scope of the research project is to develop a Conservation Plan for the two Halls designed and built by Pier Luigi Nervi in Turin Exhibition Center, with emphasis on structural and seismic issues. The project will be a mean to promote, support and guide the successive executive project of the building. An analytical investigation of Nervi’s architecture, structures, materials and construction techniques will be supported by:

- i) experimental tests on the building and its materials
- ii) dynamic vibration-based tests
- iii) historic and archival documents and direct observation
- iv) accurate geometric survey through lidar and 3D restitution.

These activities will provide clear indications and recommendations for the conservation and restoration of the building’s original characteristics, carried out by active experts of architectural heritage preservation. A special concern will be the correct modelling of the unconventional prefabricated ferrocement elements, a peculiarity of Nervi’s vaulted structures which finds in these two halls a wide spectrum of constructive variants: in Hall B the wave-like elements of the undulated vault (interestingly interfering with the glass window panels); in Hall

C the diamond panels in the central portion of the vault and the undulated beams in the perimeter area. The unique features of these components make their mechanical behavior largely uncertain and their modelling a fundamental challenge to a reliable estimation of the present and future seismic safety of Turin Exhibition Center.

4. WORKPLAN

In order to overcome the difficulties in the diagnosis and the definition of a proper conservation strategy, the research propaedeutic to the Conservation Plan for the halls in Turin Exhibition Center will be centered different work streams. The various team will work together in order to carry out this main objectives:

1. Historical analysis of the building, investigating its design and construction process, with a particular focus on its technological features and characteristics.
2. Moreover a 3D dense clouds modelling derived from 3D sensing technologies (integrated and fused image and range based methods) will be produced;
3. Structural analysis of the building, considering the construction techniques and materials. Vibration-based dynamic tests will be carried out to investigate the global behavior and the health state of the two main halls and to define guidelines for possible interventions;
4. Analysis of the materials and their durability by means of experimental investigations on structural elements and laboratory mockups. These analysis will be fundamental in the definition of guidance criteria for the materials conservation and rehabilitation
5. Definition of the overall conservation and management plan for the future renovation of the halls.

Figure 3 reports a timeline of the activities of the project. A more detailed description of the activities of the various groups can be found in the following paragraphs.

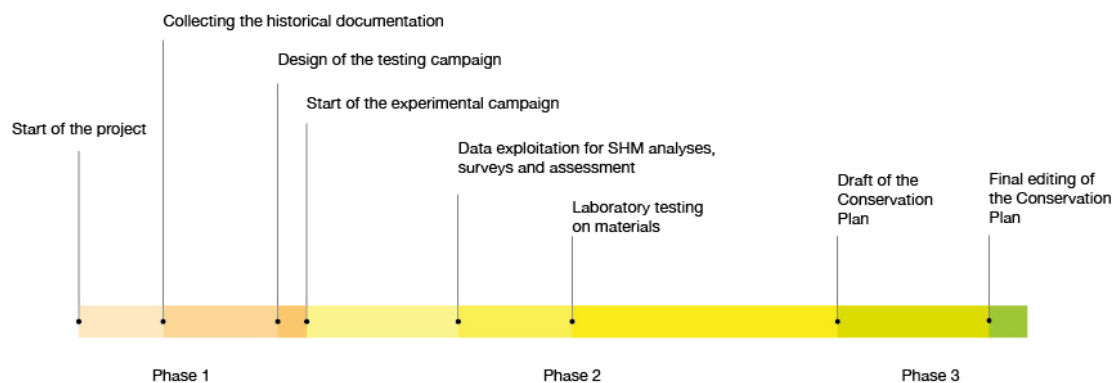


Figure 3: timeline of the project activities.

4.2 Structural Health Monitoring and Seismic assessment of the building

The first work stream is responsible for vibration-based tests and dynamic analysis in order to evaluate the response of the building to earthquakes and perform a seismic assessment of the

two Halls of the building. One of the main objective of this unit is the diagnosis of the health state of the halls. It involves a multi-scale approach based on the integration of experimental investigations carried out on-site and in the laboratory. Indeed, the conservation and rehabilitation of heritage buildings can be successfully accomplished only if a correct diagnosis has been formulated. Vibration-based structural health monitoring techniques have now become an important tool for the preservation of either antique or modern architectural heritage [11]. Dynamic tests are particularly appreciated in this field because they are a non-destructive technique and provide information about the whole-body response of the structure and its overall structural integrity. Accordingly, these techniques can in turn be undertaken for: i) understanding the structural behavior of a building; ii) assessing the response to specific events, by measuring some sensitive parameters and comparing them to typical threshold values.; iii) assessing the efficacy of structural or seismic interventions. The investigations of the structures in the dynamic and seismic domain are particularly important for this kind of structures, especially because they were designed and built to withstand only the gravity loads, accordingly to the technical standards of the time. An in-depth analysis of both hall C and B was carried out through several numerical investigations aimed at investigating the dynamic and structural response of the structures. The objective of this phase was to highlight the main criticalities of the structure and to evaluate the best strategy for the experimental campaign. An investigation of Hall C is reported in [12], while the more complex Hall B was analyzed in different steps: a preliminary model is reported in [13] and was implemented by adding the adjacent Hall A, in order to take into account the influence of an annexed structure. In the case of Hall B, the main critical aspects are connected to the large number of structural elements that govern the dynamic behavior of the structure. These macro-elements and their influence on the dynamic response of the building were described in [13]. In particular, it was pointed out that the most critical responses are those related to the undulated thin shell vault, the out-of-plane movements of the tympanums, and the presence of the apse, which cause a complex and potential vulnerable interaction with the main body of the hall. Similarly to Hall C, in Hall B bending and shear assessments were carried out on the main structural elements. Most elements, in particular the inclined pillars, are unsafe with respect to shear. Moreover, the infill walls of the tympanums are subjected to out-of-plane overturning (Figure 4).

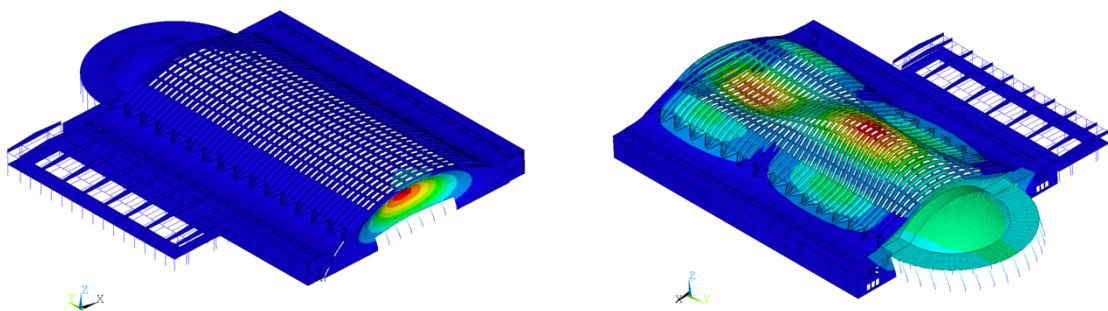


Figure 4: On the left, the out of plane movements of the front tympanum of Hall B; on the right, the interaction movements of the apse and the undulated vault.

The structure of Hall C consists of a vaulted roof supported by four inclined arches. It is completed by a perimetral slab of about 10 meters in length, sustained by a series of slim pillars and infill walls. The analysis started in [12] highlighted that the most vulnerable elements were

constituted by the dynamics of the inclined arches. These movements are amplified by their inertial mass, which is proportionally very high compared to the other elements of the hall, especially in comparison with the thin ribbed vault. Another critical aspect lies in the translation of the rigid cap of the roof with respect to the deformable contour ribs. Also due to the low ductility associated with these mechanisms, in case of moderate seismic events, the ribs may be affected by local interaction with the roof. Moreover, the main structural elements (arches, ferrocement elements, and pillars) were assessed with respect to bending and shear. In particular, results show that the arches are not verified with respect to shear loads. As a matter of fact, the shear reinforcement is weak if compared to current standards, as at the time designers were very confident about the resistance of concrete (Figure 5). Accordingly, the standards of the time only required a shear assessment for beam elements.

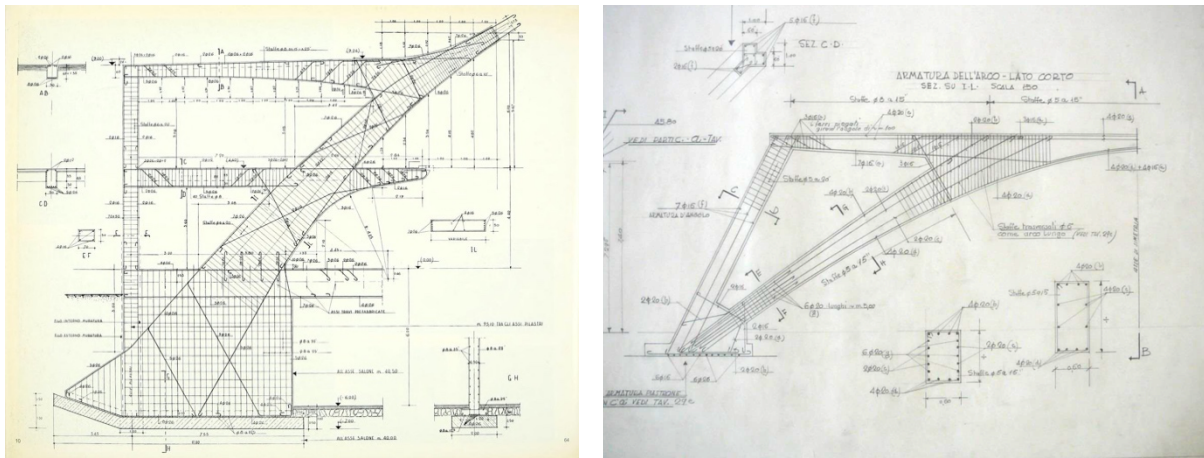


Figure 5: Original drawings reporting the details of the reinforcements of the slanted pillars of Hall B (on the left) [14], and shorter inclined arch of Hall C (on the right) [15].

4.3 Durability

This research stream will carry out the investigation, diagnosis and testing of the materials, by means of on-site inspections, and experimental investigations on materials and mockups on the ferrocement elements. The characterization of the structural materials employed in Hall B and C will be used to reproduce, with the help of the documentation of the construction procedures used by Pier Luigi Nervi (e.g. cement type and content, aggregate dimension, etc.), laboratory mockups to be subjected to an accelerated corrosion procedure. This phase of the experimental investigation is aimed to forecast the structural damage evolution of the main elements of the Turin Exhibition Center once the initiation period is over and the propagation period for corrosion of the reinforcing bar becomes effective. Once some reference level of corrosion will be over, mockups will be tested to compare their structures performances with undamaged reference specimens. Therefore, the evolution of the damage will be directly associated, to the loss of bearing capacity with safety reduction both in service and at ultimate conditions. Rehabilitation techniques as the use of FRCM (Fiber Reinforced Cementitious Matrix) or the use of other thin protective layers and of materials with effects on the cement mortar at the nanoscale will be also employed to explore their effectiveness with deteriorated ferrocement elements.

The experimental analyses will be crucial to define the guidance criteria for the materials conservation and rehabilitation for the CP of the halls, especially since the halls were built with newly patented construction systems and materials by Nervi himself.

The main aspects considered will concern:

- safety checks with respect to durability with a proposal of upgrade of the traditional systems from inspections methodologies to forecast formula of carbonation diffusion to corrosion structural damage for ferrocement construction improving the awareness of the residual safety level of the structures.
- guidelines for remedial actions and structural rehabilitation; a level of intervention priority will be proposed to check the actual conditions, plan the structural conservation activities and to suggest rehabilitations taking into consideration of the sustainability of interventions basically considering the most advanced and less invasive techniques; with reference also to the results of the experimentation on the effects on durability by additional materials as mentioned in the preceding section.

4.4 Historical Analysis and Conservation Recommendations

The conservation plan for the two halls built by Pier Luigi Nervi is an emblematic chance for research studies of structural concrete architectural heritage. The scientific approach implied in this kind of studies reflects the complexity of conservation, restoration and reuse policies requested for great works of modern architecture. This works stream has different objectives: it will closely collaborate with the other units in order to provide the necessary documentations for the first step of their action strategies. It will provide the historical and architectural analysis of the building, including archival researches as well as investigations on the relationship between architecture and construction. Moreover, it will also provide a complete accurate and dense 3D survey, and will define the conservation recommendations also considering the current Italian and European legislation framework. In fact, iconic structures, well known and appreciated and internationally recognized, are difficult examples on which to apply and reconcile any invasive structural retrofitting in terms of conservation.

The main challenges connected to this work stream are connected to various kind of criticalities. In fact, since the building had various owners, and since it has been abandoned for a long time, there is no unified and organized archive related. In particular, archives are located in different cities (Turin, Rome, and Parma), and some documents are in a precarious state of conservation, e.g. the original drawings were realized on tracing papers, which is a very fragile support. Moreover, a precise geometrical survey of the building has never been carried out and maintenance work, that could have caused changes in the interiors of the buildings, has not been adequately documented. The comparative analyses of different historical sources, such as archives, pictures, and videos, can be of great value when analyzing underestimated aspects, such as the use of color. For example some sequences of the film *The Italian job*, clearly show how the interiors of the building were painted with a cream color (Figure 6), instead of the current bright white. The use of polychromies combined with the use of natural and artificial light sources, introduce new facets in analyzing the work of Nervi that need careful reflections. This is particularly true if we consider the impact of the interventions carried out up to now, even those that were considered not-invasive, such as the operations of ordinary maintenance and some technological updates.

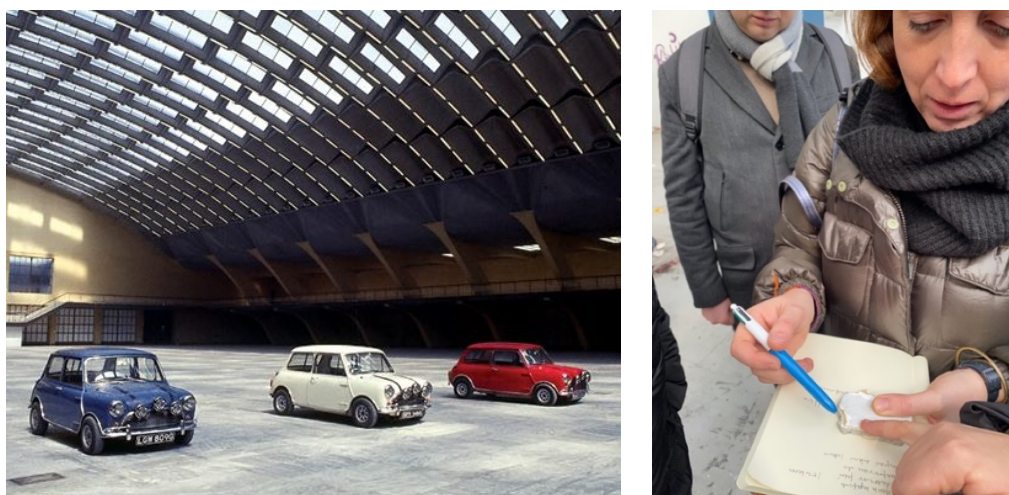


Figure 6: A frame of the movie *The Italian Job*, 1969, Peter Collinson in which it is possible to appreciate the different polychromies between the vault (painted in grey) and both the slanted pillars and the walls (painted in dark cream color). On the right, a fragment of the plaster of the hall B showing the various layers of coloring.

5 CONCLUSIONS

After years of abandonment, the celebrated spatial structures built by Nervi in the Turin Exhibition Center will be the object of an in depth analysis in order to recover them. The grant awarded by the Getty Foundation is a remarkable occasion to establish methodological criteria and guidelines for all the steps to be undertaken for an appropriate and virtuous path of structural preservation and rehabilitation. The most challenging issues to be faced in this respect concern *a)* the evaluation of the residual service life of these dated structures and the definition of adequate remedial actions to extend it in line with the new uses foreseen, and *b)* the assessment, in compliance with current Italian standards, of the structural safety and reliability of these structures with respect to seismic actions. As far as concerns item *a)*, advanced research actions are currently being initiated with respect to the assessment and prolongation of the service life of the delicate ferrocement elements of the Pavilions by Nervi. As for item *b)* a modeling and diagnostic investigations in the dynamic and seismic domain have already been performed. These investigations show some seismic vulnerabilities typical of large span shell and spatial structures that were predominantly conceived to withstand static actions and whose behavior in the dynamic domain was not taken into account in their original conception. Appropriate remedial actions, in terms of strengthening and/or damping interventions, shall be properly defined in the final stage of the reuse project.

Finally, the guidelines will have a broad range applicability, so that it will constitute a reference for possible interventions, not only on Nervi's buildings, but also on the concrete shell architectures which at the time were experimented all over the world.

Acknowledgements. The present work is supported by the Keeping it Modern grant awarded by The Getty Foundation of Los Angeles (USA). The authors would also like to acknowledge the City of Turin, owner of the buildings and active partner of the project, and Società Committenza Piemonte (SCR).

REFERENCES

- [1] K. Normandin and S. Macdonald, "A Colloquium to Advance the Practice of Conserving Modern Heritage: March 6–7, 2013: Meeting Report," The Getty Conservation Institute, Los Angeles, 2013.
- [2] T. Prudon, *Preservation of Modern Architecture*, Hoboken, NJ: John Wiley & Sons, Inc, 2008.
- [3] C. Croft, S. Macdonald and G. Ostergren, *Concrete: Case Studies in Conservation Practice*, Getty Publications , 2019.
- [4] J. Abel, G. Arun and M. Chiorino, "Special Double Issue on Pier Luigi Nervi: Preface by the Guest Editors," *Journal of the IASS*, vol. 54, no. 176-177, pp. 79-86, April 2013.
- [5] C. Chiorino and C. Olmo, *Pier Luigi Nervi. Architecture as Challenge*, Milano: Silvana Editoriale, 2010.
- [6] C. Greco, "The "ferro-cemento" of Pier Luigi Nervi, the new material and the first experimental Building," in *Proceedings of the International Symposium of IASS*, Padova, 1995.
- [7] T. Leslie, "Moving Weights: Nervi's Prefabricated 'Wave Ashlar' Roofs and the Artisanal Cantiere," in *Proceedings of the IASS-SLTE 2014 Symposium "Shells, Membranes and Spatial Structures: Footprints"*, Brasilia, 2014.
- [8] C. Greco, *Pier Luigi Nervi. Dai primi brevetti al Palazzo delle Esposizioni di Torino 1917-1948*, Lucerna: Lucerne Quart Edizioni, 2008.
- [9] T. Iori and S. Poretti, "Pier Luigi Nervi: his Construction System for Shell and Spatial Structures," *Journal of the IASS*, vol. 54, no. 176 & 177, pp. 117-126, April 2013.
- [10] ISC20C, *Approaches to the conservation of Twentieth-century cultural heritage Madrid – New Delhi Document*, ICOMOS International Committee on Twentieth Century Heritage , 2017.
- [11] R. d. L. G. L. E. M. G. Ceravolo, "Seismic structural health monitoring of cultural heritage structures," in *Seismic structural health monitoring*, Springer Tracts in Civil Engineering, 2019, pp. pp. 51-85.
- [12] E. Lenticchia, R. Ceravolo and C. Chiorino, "Damage scenario-driven strategies for the seismic monitoring of XX century spatial structures with application to Pier Luigi Nervi's Turin Exhibition Centre," *Engineering Structures*, no. 137, pp. 256-267, 2017.
- [13] E. Lenticchia, R. Ceravolo and P. Antonaci, "Sensor Placement Strategies for the Seismic Monitoring of Complex Vaulted Structures of the Modern Architectural Heritage," *Shock and Vibration*, no. art. no. 3739690 DOI: 10.1155/2018/3739690, 2018
- [14] P. Nervi, *Aesthetics and Technology in Building, The Charles Eliot Norton Lectures* ed., Harvard University Press, 1965.
- [15] P. L. Nervi, "Palazzo delle Esposizioni - Torino (original projects)," *Centro Studi e Archivio della Comunicazione (CSAC) , Parma*, 1948-53.

AUTHORS INDEX

Aşikoğlu, A.....	2858	Bai, W.....	2993, 3077
Abdalla, S.B.....	1641	Bajramovic, A.....	2768
Abelezele, S.A.....	1170	Baldantoni, F.....	2586
Abuhatsira, D.....	1478	Balik, L.....	3381
Achig, M.C.....	1393	Baraldi, D.....	1755
Adam, J.M.....	626, 2737, 3438	Barbo, S.....	3065
Adamek, J.....	2306	Barchetta, L.....	2824
Addressi, D.....	1893, 2217	Barou, L.....	1571
Adell, J.M.....	279	Barroso, C.E.....	809
Aguilar, R.....	504, 1618, 3145, 3218	Barsallo, G.....	1393
Aita, D.....	433, 1338	Barsi, F.....	1338
Al Shawa, O.....	651, 2894	Barsotti, R.....	1338
Alaboz, M.....	3005	Basaglia, A.....	2757, 3402
Alfaro, C.....	302, 3652	Basirico, T.....	1133
Alonso, E. M.....	769	Basso, A.....	1547
Alonso-Martinez, M.....	1145	Bayer, J.....	802
Alvarez-Rabanal, F.P.....	1145	Bedolla, J. A.....	769
Alykow, K.....	1206	Bedoya, C.....	279
Amano, Y.....	3240	Belleri, A.....	2926
Amato, G.....	2642	Bellin, S.....	3181
Amorosi, A.....	933, 2780	Bellini, A.....	2620
Andic, D.....	2708	Benedetti, A.....	1871
Angelillo, M.....	445, 2066	Benedetti, L.....	1871
Angjeliu, G.....	1834	Bennati, S.....	1338
Antuna, J.....	2240	Bento, R.....	1457, 2870
Anzilotti, Y.....	3065	Berardi, R.....	1074
Aoki, T.....	2696	Berkowski, P.....	144, 897
Apak, K.....	2600	Berlucchi, N.....	3169
Aprile, A.....	2757	Bernardi, P.....	1502
Argiento, L.....	2007	Bernardini, G.....	3486
Argiento, L.U.....	614	Bernat-Maso, E.....	746
Aripov, I.....	3339	Berto, L.....	3181
Arleo, L.....	3193	Bertolesi, E.....	626, 2737
Arroyo Matus, R.....	3371	Bertolin, C.....	791, 3284
Artioli, G.....	2564	Betti, M.....	1109
Asad, M.....	537	Biagini, C.....	421
Askouni, P.D.....	2528	Bianchini, N.....	3098
Auletta, G.....	2586	Biggs, D.....	1222
Aurelio Felicito, R.....	3371	Bisegna, P.....	2088, 2425
Autiero, F.....	492	Bishara, S.....	1559
Avşar, O.....	2858	Blank, M.....	1303
Aznar, A.....	2240	Block, P.....	1736, 1882, 2019, 2124, 2846
Álvarez, I.....	3498	Blondet, M.....	3133
Badillo-Almaraz, H.....	2354	Bocan, C.....	1535
Baez, J.....	257	Boem, I.....	2470
Baeza, F.J.....	559	Boggian, F.....	2958
Baggio, C.....	943, 2282, 3252	Boothby, T.....	2318

Bordo, D.	1490	Cascini, L.....	1014
Boriani, M.	3426	Castañeda, B.....	504, 1618
Borin, P.	1547	Castellano, A.	722, 1959, 2504
Borlenghi, P.	697	Cattari, S.....	3016
Boroschek, R.	3218	Cavalagli, N.	2100, 2552
Bourgeois, E.	2400	Cazzani, A.	2342
Bozza, E.	821	Cecil, R.T.	1170
Bracchi, S.	2946, 3028	Čejka, T.....	2687
Bragadin, M.A.....	2790	Celano, T.	1846, 2007
Braglia, V.	267	Celik, O. C.	1675
Brando, G.	302, 3402, 3641, 3652	Cennamo, C.	445
Brencich, A.	59	Ceraldi, C.....	614
Bristogianni, T.	1571	Ceravolo, R.....	71, 1996
Briz, E.	117, 3498	Cerioni, R.....	1502
Brookes, S.	1409	Ceroni, F.	2007
Brožovský, J.	2687	Charpis, D.C.....	200
Bru, D.	559	Chaves Moreno, E.A.	2054
Brugnera, P.....	47	Chácara, C.	2294
Bucur-Horváth, I.	94	Chávez, M.	757, 2882, 2938
Buitrago, M.	626, 2737	Chen, J.F.	2642
Burrill, S.	3349	Chenyi, L.	2378
Bustamanta-Altamirano, J.	1663	Chesi, C.....	3426
Cabané, A.....	662	Chieffo, N.....	3522, 3581
Cabezas, K.	325	Chiorino, C.....	71
Cacace, D.....	2262	Chiozzi, A.....	1971
Cacciotti, R.	2836	Chisari, C.....	1724
Caddemi, S.....	2612	Chounta, A.....	3109
Calì, A.	1158	Chun, Q.	1214
Calderón, P.A.....	626, 2737	Chunxia, Y.	2378
Calderini, C.....	569, 1074, 1256, 3098	Cianchetti, R.....	1421
Cali, A.	1315	Cianchino, G.....	3641
Caliò, I.	909, 2007, 2294, 2612	Cianci, E.	2802
Camassa, D.....	559	Ciocchi, M.P.....	1811, 1846
Camata, G.	1789, 1928, 2516	Clark, K.....	1409
Cambiaggi, L.	1074, 1256	Cluni, F.....	1651
Campione, S.....	1133	Coisson, E.....	267, 1687
Campos Costa, A.....	3098	Coccia, S.	397
Candeias, P.	3098	Cocco, G.....	3652
Candela, M.....	1050	Cocking, S.H.....	2066
Cannizzaro, F.....	909, 1002, 2294, 2612	Cocuzza Avellino, G.	909
Cantini, L.	469	Coisson, E.	1502
Caprili, S.....	2076	Coll Pla, S.....	1086
Cardani, G.	1834	Colucci, A.....	3252
Cardona, O. D.	885	Comert, M.....	3169
Cardoso, F.	1393	Cominelli, S.	2926
Carloni, C.....	2451	Condoleo, P.	3156
Carranza Bello, J. L.....	3371	Cooke, J.	978
Carvalho, J.	852	Cordero Espinosa, L.....	734
Casapulla, C.....	614, 1822, 1846, 2007	Corlito, V.....	2262, 3474, 3605
Casarin, F.	639, 821, 1369, 1421	Coronelli, D.....	1834

Costa, M.G.	47	Di Martino, A.	909
Costa-Jover, A.	1086	Di Napoli, B.	1846
Cottone, A.	1133	Di Sivo, M.	1490
Coz-Diaz, J.J.	1145	Dias De Moraes, P.	1158
Crété, E.	3193	Dimovska, S.	3569
Crespi, P.G.	1699	Dinç-Şengönül, B.	2136
Croonenborghs, T.	1268	Dmochowski, G.	144, 897
Cucchi, M.	830	Do Valle, A.	1158
Cusano, C.	445	Dobon, J.	2664, 2729
Cusmano, V.	1002	Dogu, D.	1291
D'Angelo, F.	2718	Dongmo, B.F.	3181
D'Anna, J.	2642	Doran, B.	2136
Da Gai, E.	943	Dos Santos, M.N.	1170
Dahabreh, P.	1369	Douroux, J. F.	2400
Dai, J.	2993, 3077	Drdácký, M.	2836
Daigo, T.	3296	Drdácký, T.	2836
Dalla Via, T.	1421	Drdácky, M.	639
Damiani, N.	2946	Drougkas, A.	1268
Dauda, J. A.	2206, 2576	Drygiannakis, M.	3272
De Angelis, A.	1097	Durán, D.	2882
De Bellis, M.L.	2043	Dutu, A.	2181
De Canio, G.	651, 2894	Džombić, N.M.	1026
De Cesaris, F.	966	Edmisten, J.	2330
De Falco, A.	1490	Egiluz, Z.	117
De Felice, G.	651, 933, 1917, 2632, 2780, 2894	Eichberg, M.	1050
De Ferri, L.	791, 3284	Enciso, R.	3145
De Filippis, L.	1097	Endo, Y.	1778, 3264
De La Llera, J.C.	1244, 2439	Esparza-Carrillo, A.	1663
De La Rosa, S.G.	2354	Esponda, M.	734, 978
De Lucia, G.	71, 1996	Esposito, R.	2652
De Martino, G.	492	Facchi, E.	373
De Matteis, C.	3641	Falcão, A. P.	1457
De Matteis, G.	2262, 3474, 3605	Farahza, N.	3193
De Santis, S.	651, 2632, 2894	Fenialdi, A.	1256
Declercq, P. Y.	1268	Fernández, J.	3121
Degli Abbatì, S.	3016	Ferrari, L.	267
DeJong, M.J.	2066, 2846	Ferrández, A.	3121
Delagrammatikas, M.	2480	Ferrero, C.	569, 1074, 1256
Dell'Endice, A.	1882, 2019	Ferretti, D.	1687
Della Torre, S.	469, 674, 3510	Ferretti, F.	525, 2540
Demir, C.	3169	Figueiredo, R.	2746
Demirlioglu, K.	3558	Fioriti, V.	3252
Desbordes, A.	2400	Florea, M.	1183
Di Biase, C.	385	Flores-Sasso, V.	921, 1470
Di Carlo, F.	397	Fontana, C.	2802
Di Gennaro, L.	2718	Foppoli, D.	674
Di Ludovico, M.	492	Forliti, S.	651, 2894, 3252
Di Marco, L.	1369	Formigoni, F.	1971
Di Marco, S.	2790	Formisano, A.	3522, 3581
		Fraddosio, A.	722, 1959, 2504

Franchi, A.	1699	González-Aguilera, D.	1559
Franzoni, E.	2451	Grandic, D.	245
Friedman, D.	1947	Grandits, D.	1038
Frostick, R.	1409	Graziotti, F.	2946, 3028
Frunzio, G.	2718	Greppi, A.	385
Fuentes Rivera, G.I.	3065	Grillanda, N.	1971, 2342
Fuertes, P.	361	Grimes, M.	593
Fugger, R.	1917	Grimoldi, A.	373
Funari, M.F.	211	Grottesi, G.	791
Fusco, D.	2217	Guerrini, G.	2946
Gaglio, F.	1490	Guntur, M.	954
Galassi, S.	2413	Gusella, V.	1651, 2100, 2552
Gandini, A.	117	Hadid, S.	1478
Garbin, E.	2564	Hadjimichael, M.M.	82
García, J.	3121	Hajmirbaba, M.	3193
García, N.	2882	Haldenwang, R.	515
García-Alvarez, J.	1559	Halici, O.F.	3169
García-Baltodano, K.	1326	Hamamoto, T.	3296
García-Muñoz, J.	2112	Hassanieh, A.	1766
García-Cuetos, M.P.	1145	Hatletveit, M.	2958
García-Ramonda, L.	2516	Hayen, R.	1268
Gard, W.	709	Höst, F.	1799
Garmendia, L.	117, 3498	Herbig, U.	1038
Garnier, P.	3193	Hernando, J.I.	2240
Gattesco, N.	2470	Hernández-Salazar, I.	1326
Gáspár, O.	1984, 2229	Hettinga, J.	1232
Gendelman, P.	1478	Hicks, N.A.	2914
Gentile, C.	697, 1315, 1346, 3305	Higashizawa, B.	1859
Gentilini, C.	2451	Hola, A.	842
Georgiou, A.V.	82	Hola, J.	842
Gharib, M.	1766	Holowaty, J.	781
Giambruno, M.C.	3426	Hormazábal, M.F.	3317
Gianfriddo, G.	909	Horvat, M.	2708
Giannetti, I.	397	Hosamo, H.	873
Giardina, G.	1905	Hothot, Y.M.	2136
Gil, L.	746	Hrivnák, J.	639
Giordano, A.	1547	Huaranga, S.	1618
Girardi, M.	2031	Huizinga, W.	1905
Giresini, L.	2168	Hurata, A.	3169
Gisbert, I.	559	Iannuzzo, A.	1882, 2019, 2124
Giuliani, F.	1490	Ilić, I.D.	1026
Giuliano, A.A.	1433	Ilki, A.	3169
Giuriani, E.	2926	Illampas, R.	1062
Gobbin, F.	1917	Impollonia, N.	909
Godinho, M.	1457	Incerti, A.	525, 2540, 2620
Gonçalves, A. B.	1457	Intrigila, C.	2425
Gonzalez, A.	3402	Ioannou, I.	82, 1062
Gonzalez-Libreros, J.	2612	Ion, A.C.	1594
González, G.A.	2354	Ireland, R.	1409
González, J. A.	2318	Isopescu, B.	1122

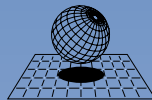
Iuorio, O.....	2206, 2576	Lembo, F.....	2586
Ivorra, S.....	559, 626	Lenticchia, E.....	71
Iwanami, G.....	1778	Li, X.....	2673
Iwicki, P.....	409	Liberatore, D.....	651, 2894, 3661
Izzuddin, B.A.....	1724	Liberotti, R.....	1651, 2100, 2552
Jaeger-Klein, C.....	2768	Licciardello, L.....	2652
Jara, J.M.....	3052	Liew, A.....	1736, 2846
Jasieńko, C.....	602	Lin, Y.....	1214
Jiménez Rios, A.....	593	Lindenbergh, R.....	709
Jimenez, B.....	2194	Liu, C.....	990
Kabele, P.....	2306	Lluis i Ginovart, J.....	685, 1086
Kalagri, A.....	2480	Lluis-Teruel, C.....	685
Kalkbrenner, P.....	1712	Lo Faro, A.....	1002
Kaminsky, J.....	547	Loke, M. E.....	515
Kao, G.T.C.....	1882	Lopez-Piquer, M.....	685
Kapogianni, E.....	291, 3329	Lorenzoni, F.....	2251
Karolak, A.....	602	Lourenço, P.B.....	211, 1746, 1811, 1846, 1893, 2007, 2206, 2294, 2576, 2858, 3098, 3218, 3581
Kaymak Heinz, G.....	233	Lozano Martinez-Luengas, A.....	1145
Keller, A.....	1122, 1535	Lubelli, B.....	105
Keller, A.I.....	2902	Lubowiecka, I.....	2274
Key, E.T.....	2054	Lucesoli, M.....	3486
Kido, T.....	3240	Lysandrou, V.....	1062
King, M.....	1766	Macaya, F.....	757
Kioumars, M.....	873	Machete, R.....	1457
Kloiber, M.....	639	Macorini, L.....	1724
Kněž, P.....	2156	Maddaloni, G.....	1097
Koch, M.....	325	Maeda, T.....	1859
Kodzoman, E.....	1038	Magdalena, F.....	2240
Koh, B.....	2330	Magdalena-Layos, F.....	2112
Kolísko, J.....	2156	Maia Avelino, R.....	1882, 2124
Kondo, Y.....	1778	Maino, S.....	325
Konsta, A.....	3510	Maklada, N.....	1478
Korslund, K.A.....	1170	Makoond, N.....	1291, 3228
Kosciuk, J.....	481	Malakoudi, C.....	3109
Kruithof, M.....	1905	Malcata, M.....	2870
Kubát, J.....	2687	Marano, C.....	1789, 1928
Kudrnacova, L.....	3381	Marcos, I.....	117
Kumar, A.....	1279	Margani, G.....	2958
Kundu, T.....	722	Mariano, F.....	1433
Kuran, F.....	3169	Marini, A.....	2926
Kurata, N.....	3296	Marino, E.....	2958
Kurniawan, K. R.....	954	Marino, F.P.R.....	2586
La Mendola, L.....	2642	Marotta, A.....	3661
Ladiana, D.....	1490	Marques, R.....	1811
Lagomarsino, S.....	3016	Martinez, G.....	3052
Landi, A. G.....	373	Martini, R.....	852
Landolfo, R.....	1014	Martins, T.....	3121
Lapucci, D.....	2824	Masciotta, M.G.....	1559, 3317
López López, D.....	1736		
Leggieri, V.....	3414		

Massaro, L.....	2718	Natali, M.	2564
Matracchi, P.....	421	Nebiacolombo, M.....	59
Matrasulov, D.....	3339	Nedvedova, K.....	3381
Matta, E.....	71	Nicol, L.M.....	156
Mazzanti, C.....	302, 3652	Nicolaou, D.....	1062
Mazzotti, C.....	525, 2540, 2620	Niculescu, M.....	1183
Mària, M.....	1445	Niitsu, Y.....	3264
Meade, E.P.....	2914	Nijse, R.....	1571
Meggiato, M.....	1421	Nocera, M.....	1893
Mehrotra, A.....	2330, 2846	Nodargi, N.A.....	2088, 2425
Mejia, L.....	3052	Noel, M.....	3145
Mencías-Carrizosa, D.....	2112	Nollet, M-J.....	3593
Mendes, N.....	3098	Nuñez, E.....	757
Mentese, V. G.....	1675	O'Dwyer, D.....	593
Mercedes, L.....	746	Occhipinti, G.....	2802
Meriggi, P.....	2632, 2894	Ohashi, Y.....	3087
Messali, F.....	2217, 3028	Oikonomopoulou, F.....	1571
Michelini, E.....	1502	Okada, M.....	3240
Miglietta, M.....	2946	Oktay, D.....	2136
Milani, G.....	1746, 1755, 1971, 2342, 2492, 2504, 2981	Olagoke, O.A.....	1514
Mileto, C.....	2814	Olazabal, M.....	3498
Miltiadou-Fezans, A.....	2480	Oliveira, B.....	1523
Minafò, G.....	2642	Oliveira, D.V.....	211, 809, 1559, 2168, 3317
Minch, M.....	144, 897	Olivieri, C.....	2066
Mirabella Roberti, G.....	47	Olivito, R.S.....	2492
Mirabile Gattia, D.....	651	Olmos, B.....	3052
Miraglia, G.....	71	Olstad, T.M.....	3284
Misseri, G.....	1244, 2439	Onescu, E.....	3546
Miyamoto, M.....	2366, 2390, 2696, 3240	Onescu, I.....	3546
Mocellini, M.....	1369, 1421	Oprita, R.....	127
Molins, C.....	1291, 3228	Orduña, A.....	2354
Montenegro, E.....	3617	Ortega, J.....	2054, 3534
Monteys, X.....	1445	Ota, K.....	3240
Moragues, J.J.....	626, 2737	Ottonelli, D.....	3016
Moreno Garcia, D.....	1086	Ottoni, F.....	267
Moreno Regan, O.....	2400	Oyarzo, C.....	757
Mornati, S.....	397	Oz, Y.....	1478
Morrison, T.....	3349	Paşcu, G.....	1535
Mosoarca, M.....	1122, 1183, 1594, 2902, 3546, 3581	Pachta, V.....	581
Mosseri, A.....	337	Padovani, C.....	2031
Mourek, J.....	1303	Pagliari, F.....	1687
Mousavian, E.....	614, 1822	Pakowska, M.....	481
Murai, S.....	2366	Palade, M.....	1183
Myrianthefs, D.....	1062	Palazzi, N.C.....	1244, 2439
Naldini, S.....	105, 1583	Palinic, N.....	245
Nan, Z.....	2378	Pallav, K.....	515, 1279
Nanni, A.....	2620	Pampanin, S.....	2217
Napiórkowska-Alykow, M.....	1206	Panizza, M.....	2564
		Pantò, B.....	1002, 1724, 2007, 2294
		Papanicolaou, C.G.....	2528

Papasavvas, G.	1062	Prieto, S. D.	885
Pardo Redondo, G.	105	Prieto-Vicioso, E.	921, 1470
Paret, T.F.	2458	Prota, A.	492
Parisi, M.A.	3065, 3593	Przewlocki, J.	409
Parisse, F.	2181	Psarropoulos, P.	3329
Passoni, C.	2926	Puncello, I.	2076
Pasterkamp, S.	192	Quagliarini, E.	3486
Paterno, E.	909	Quattrone, A.	71
Paupério, E.	2746, 3450	Quesada-Ganuza, L.	3498
Pavel, F.	3462	Ragueneau, M.	1940
Pérez-Cuevas, J.	921	Rajabzadeh, S.	734
Pórcel, P.	1618	Rakhmanov, B.	3361
Peña, F.	2882, 2938	Ramos, L.F.	809
Pecce, M.R.	1097	Rampello, S.	933
Pejatovic, M.	2981	Randall, L.	1409
Pelà, L.	662, 1712, 1789, 2194, 2516, 2757, 3228, 3569	Rapicavoli, D.	2294, 2612
Pellegrini, D.	2031	Rashid, M.	1641
Pellegrino, C.	2612	Rautenberg, J.M.	2458
Pema, P.	2696	Rózsás, A.	1905
Penna, A.	2946, 3028	Reccia, E.	2342
Perobelli, S.	651	Ricci, E.	1959
Perria, E.	2673	Riggio, M.	3206
Persia, F.	651	Rihal, S.	2330
Perucchio, R.	457, 1170	Rinaldi, Z.	397
Peruch, M.	3652	Rjolli, L.	1490
Petetta, L.	1433	Roca, P.	569, 662, 1256, 1629, 1736, 2076, 2262, 2516, 3228, 3474, 3534, 3569
Petracca, M.	1789, 1928	Rocca, I.	3181
Petridis, C.	3109	Rodas, T.	1393
Petrou, M.L.	200	Rodrigues, H.	2181
Petrović, M.	1026	Rodriguez-Mariscal, J.D.	852
Petrucci, E.	2824	Roeder, G.M.	2354
Philokyprou, M.	1062	Rojí, E.	3498
Piñero, I.	117	Romagnoli, G.	2802
Piccinini, F.	1433	Romão, X.	2746, 3450
Piccioni, M.D.	722, 1959, 2504	Roscini, F.	2632
Pino, O.	2054	Roselli, I.	2894, 3252
Pintus, V.	2342	Rossi, M.	569, 3098
Pisarra, W.	2814	Rossi, R.	1712
Pitilakis, D.	3109	Rots, J.G.	2217, 2652
Plevris, V.	873	Rouhi, A.	168, 180
Pojatina, J.	2708	Rovero, L.	1244, 2439
Poletti, E.	2054	Ruccolo, A.	3305
Poletti, E.	2181	Rucka, M.	863
Ponte, M.	1457, 2870	Ruggieri, S.	3414
Ponzo, F.C.	2586	Ruiz-Valero, L.	921, 1470
Porcel, P.	504	Sabbatini, V.	943, 2251, 3252
Porras-Alfaro, D.	1326	Sabri, R.	1514, 1641
Portioli, F.	1014	Sacco, E.	1959
Porzio, S.	2492		

Sadocchi, A.....	421	Shehu, R.....	2970
Sadowski, L.....	842	Shimoni, M.....	1268
Saetta, A.....	3181	Shin, S.....	2696
Saisi, A.....	697, 1315, 3305	Shirahashi, M.....	1859
Saitta, F.....	3252	Shrestha, K.C.....	2696
Sajtos, I.....	1984, 2229	Shrive, N.....	168
Sakellariou, M.....	3329	Shrive, N.G.....	180
Sala, M.....	674	Shu, C.....	2378
Salas, C.....	279	Siani, A. M.....	791
Salazar, L.G.....	3450	Siboni, D.....	1478
Saloustros, S.....	3534, 3569	Sidawi, R.....	1369
Salvadó, N.....	361	Sieder, M.....	2673
Salvalaggio, M.....	2251	Siedler, G.....	547
Sammartano, G.....	71	Sieffert, Y.....	3193
Samol, P.....	409	Siegert, S.....	2673
Sampaio, M.S.....	221	Sielicki, P.W.....	137
Sandoval, C.....	2439	Silva, L.C.....	211, 1893, 2206, 2858
Sandoval, S.....	921	Simoncello, N.....	2612
Sangiorgio, V.....	3438	Šimunić Buršić, M.I.....	349
Sangirardi, M.....	933, 2780	Sinchi, E.....	1393
Santa Ana, L.....	257	Sinopoli, A.....	433
Santa Ana, P.....	257	Sipos, A.....	1984
Santa Cruz, S.....	3133	Sipos, A. A.....	2229
Santamato, F.....	1097	Sire, S.....	1940
Santini, S.....	943, 2282, 3252	Slobbe, A.....	1905
Santoro, R.....	2451	Solarino, F.....	2168
Sanver, A.N.....	3169	Solís, M.....	852
Saracco, M.....	1433	Soria, M.A.....	2664, 2729
Saretta, Y.....	3390	Sorrentino, L.....	651, 2894, 3661
Sarhosis, V.....	1755, 2981	Sovero, K.....	302, 3652
Saruwatari, S.....	3296	Soyoz, S.....	3558
Sauquet, R.....	361	Spacone, E.....	302, 1789, 1928, 2757, 3402, 3652
Sánchez, A.....	769	Spano, A.....	71
Sánchez Tizapa, S.....	3371	Spinelli, P.....	1109
Sánchez-Aparicio, L.J.....	1559	Stabrauskaite, D.....	1606
Sbrogiò, L.....	1547, 3390	Stampfer, L.....	1038, 2768
Scacco, J.....	1746, 2504	Stefanidou, M.....	581
Scamardo, M.....	1699	Stoian, V.....	1122, 1183
Scancelli, L.....	639, 821	Strojecki, M.....	791
Schaaf, U.....	1381	Stumpf, W.....	1194
Šculac, P.....	245	Suárez, J.....	2318
Scupin, A.....	3462	Sumali, A.....	1358
Scuro, C.....	2492	Sun, J.....	457
Sebastiani, C.....	943, 3252	Szepietowska, K.....	2274
Šekularac, N.D.....	1026	Szolomicki, J.....	144, 897
Sepe, V.....	2043	Szymanowski, J.....	842
Sesigur, H.....	3005	Takahashi, N.....	2696
Setyastuti, A.....	1038	Takai, K.....	3296
Sferrazza Papa, G.....	3065, 3593	Takhirov, S.....	3361
Shabani, A.....	873		

Takhirov, S.M.	3339	Van der Grijp, E.	1583
Taliercio, A.	3156	Van Hees, R.	1583
Tamburini, S.	2564	Van Mele, T.	1736, 1882, 2019, 2124
Tanaka, H.	1859	Varum, H.	852
Tarantino, C.	1014, 1050	Vasconcelos, G.	2054
Tardo, C.	2958	Vassiliou, P.	2480
Tarozzi, M.	1871	Vasta, M.	2043
Tarque, N.	302, 3121, 3652	Vázquez Jiménez, R.	3371
Taweel, A.K.	1369	Vecchiattini, R.	1074, 1256
Tedeschi, C.	830	Veer, F.A.	1571
Tej, P.	1303, 2156	Vegas López-Manzanares, F.	2814
Tempesta, G.	2413	Vera, E.	1402
Teneva, E.	746	Verstrynge, E.	1268
Tenzin, K.	2696	Vetter, S.	547
Tezcan, S.	457, 1170	Virág, J.	94
Thamboo, J.	537	Vitaliani, R.	3181
Thelin, C.	1799	Vlachakis, G.	3272
Theodossopoulos, D.	990	Vona, V.	3629
Tiberti, S.	2492	Walstra, J.	1268
Tisserand, P.-J.	1940	Wangmo, P.	2696
Tomasi, R.	2958	Wasilewski, K.	2146
Tomioka, A.	3296	Wenliuhan, H.	2251
Tondolo, F.	71	Wibaut, R.	313
Tonietti, U.	2439	Wichtowski, B.	781
Tonna, S.	830, 3426	Witzany, J.	802, 2687
Torres, A.	3133	Woudenberg, P.	709
Torres, B.	559, 626	Wouters, I.	313
Torres-Acosta, A.	1663	Wu, B.	2993
Tralli, A.	1971	Yadav, S.	3193
Traykov, A.V.	3040	Yamasaki, T.	3240
Traykova, M.D.	3040	Yang, Y.	3077
Trizio, F.	2814	Yaya, C.	1618
Truong-Hong, L.	709	Yüzer, N.	2136
Tzigounaki, A.	3272	Yokouchi, H.	3087
Ulivieri, D.	1338	Yuasa, N.	2696
Ulukaya, S.	2136	Zahra, T.	537
Uplekar, A.	2054	Zamperini, E.	373
Urushadze, S.	802	Zampieri, P.	2612
Uva, G.	3414, 3438	Zbiciak, A.	2146
Vacareanu, R.	3462	Zhang, C.	1214
Valente, M.	1971	Zhang, J.	2696
Valenti, R.	909	Zielińska, M.	863
Valieri, M.	421	Zigler, R.	2687
Valluzzi, M.R.	639, 821, 1547, 2251, 3390	Zizi, M.	2262, 3605
Van Balen, K.	1268	Zonno, G.	1346, 3218
Van de Kuilen, J.-W.	709	Zuppiroli, M.	3629



CIMNE⁹

International Center
for Numerical Methods in Engineering