

THE INTERNATIONAL CONFERENCE  
SYNERGY OF ARCHITECTURE & CIVIL ENGINEERING  
**SINARG 2023**

---

**PROCEEDINGS**

---

**VOLUME 2**



International Conference

**Synergy of  
Architecture &  
Civil Engineering**

Niš (SERBIA) - Science & Technology Park Niš - September 14-15, 2023

---

**PROCEEDINGS OF THE INTERNATIONAL CONFERENCE  
SYNERGY OF ARCHITECTURE & CIVIL ENGINEERING  
SINARG 2023**

**VOLUME 2**

**PUBLISHED BY:**

FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE, UNIVERSITY OF NIŠ  
SERBIAN ACADEMY OF SCIENCES AND ARTS - BRANCH IN NIŠ

**FOR PUBLISHERS:**

SLAVIŠA TRAJKOVIĆ, PHD  
VLADA VELJKOVIĆ, PHD

**EDITORS:**

SLAVIŠA TRAJKOVIĆ, PHD  
VUK MILOŠEVIĆ, PHD

APPROVED TO BE PRINTED ON 7TH SEPTEMBER 2023. BY THE DECREE OF TEACHING SCIENTIFIC COUNCIL OF THE FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE, UNIVERSITY OF NIŠ, NO. 8/181

APPROVED TO BE PRINTED ON 4TH SEPTEMBER 2023. BY THE COMMITTEE FOR MANAGING THE WORK OF THE SERBIAN ACADEMY OF SCIENCES AND ARTS - BRANCH IN NIŠ, NO. 1/23-159

**TECHNICAL EDITOR:** DUŠAN RANĐELOVIĆ, PHD

**COVER DESIGN:** LJILJANA JEVREMOVIĆ, PHD

**ISBN** 978-86-88601-81-8

**ISBN** 978-86-88601-82-5 (FOR PUBLISHING ISSUE)

**PRESS:** 100 COPIES

**PRINTED BY:** GRAFIKA GALEB NIŠ

**ORGANIZED BY:**

FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE, UNIVERSITY OF NIŠ  
SERBIAN ACADEMY OF SCIENCES AND ARTS - BRANCH IN NIŠ  
SERBIAN ACADEMY OF SCIENCES AND ARTS - DEPARTMENT OF TECHNICAL SCIENCES

**IN PARTNERSHIP WITH**

SCIENCE TECHNOLOGY PARK NIŠ



**SCIENCE  
TECHNOLOGY  
PARK  
NIS**

THE ORGANISATION OF THE INTERNATIONAL CONFERENCE  
**SYNERGY OF ARCHITECTURE AND CIVIL ENGINEERING - SINARG 2023**  
AND PRINTING OF THE PROCEEDINGS HAS BEEN SUPPORTED BY THE  
**MINISTRY OF SCIENCE, TECHNOLOGICAL DEVELOPMENT AND INNOVATION,**  
**REPUBLIC OF SERBIA**  
AND  
**SERBIAN CHAMBER OF ENGINEERS.**



Ministry of Science, Technological  
Development and Innovation  
of the Republic of Serbia



ИНЖЕЊЕРСКА КОМОРА  
СРБИЈЕ

## SCIENTIFIC PROGRAM COMMITTEE

### CO-CHAIRS:

**Academician Dušan Teodorović**, PhD, Serbian Academy of Sciences and Arts, Belgrade, Serbia  
**Academician Branislav Mitrović**, Serbian Academy of Sciences and Arts, Belgrade, Serbia

### MEMBERS:

**Academician Fedor Mesinger**, PhD, Serbian Academy of Sciences and Arts, Belgrade, Serbia  
**Professor Günther Meschke**, PhD, Ruhr University, Bochum, Germany (Editor-in-Chief, Engineering Structures)  
**Professor Momcilo Markus**, PhD, University of Illinois, Urbana-Champaign, USA (Editor-in-Chief, JAWRA)  
**Professor Janos Logo**, PhD, BME University, Budapest, Hungary (Editor-in-Chief, Periodica Polytechnica Civil Engineering)  
**Professor Hartmut Pasternak**, PhD, Brandenburg University of Technology, Cottbus, Germany  
**Professor Sandra Klinge**, PhD, Technical University Berlin, Germany  
**Professor Naomi Ando**, PhD, Hosei University, Tokyo, Japan  
**Associate Professor Zakhar Maletskyi**, PhD, Norwegian University of Life Sciences (NMBU), As, Norway  
**Senior Lecturer Milena Metalkova-Markova**, PhD, University of Portsmouth, Portsmouth, United Kingdom  
**Associate Professor Oliveir Gaudin**, PhD, Ecole Nature et Paysage / INSA Centre Val de Loire, Blois, France  
**Professor Giuseppe Tito Aronica**, PhD, University of Messina, Italy  
**Adjunct Professor Elena Lucchi**, PhD, Politecnico di Milano, Italy  
**Associate Professor Michael Tritthart**, PhD, University of Natural Resources (BOKU), Wien, Austria  
**Professor Georgios E. Stavroulakis**, PhD, Technical University of Crete, Chania, Greece  
**Research Associate Charalampos Skoulikaris**, PhD, Aristotle University of Thessaloniki, Greece  
**Associate Professor Janusz Marchwiński**, PhD, University of Ecology and Management, Warsaw, Poland  
**Assistant Professor Monika Magdziak**, PhD, Bialystok University of Technology, Poland  
**Associate Professor Martin Horáček**, PhD, Brno University of Technology, Czech Republic  
**Professor Martina Zelenakova**, PhD, Technical University of Kosice, Slovakia  
**Professor Beatrice-Gabriela Jöger**, PhD, Ion Mincu University of Architecture and Urbanism, Bucharest, Romania  
**Research Associate Constanta Carmina Gheoghita**, PhD, Technical University of Iasi, Romania  
**Associate Professor Petar Filkov**, PhD, University of Architecture, Civil Engineering and Geodesy (UACG), Sofia, Bulgaria  
**Associate Professor Stefan Asparuhov**, PhD, University of Architecture, Civil Engineering and Geodesy (UACG), Sofia, Bulgaria  
**Associate Professor Filiz Karakuş**, PhD, Ankara Yildirim Beyazit University, Ankara, Türkiye  
**Senior Lecturer Jan-Frederik Flor**, PhD, University of Malaysia, Kelantan, Malaysia  
**Associate Professor Davorin Penava**, PhD, University of Osijek, Croatia  
**Professor Barbara Karleuša**, PhD, University of Rijeka, Croatia  
**Associate Professor Darija Gajić**, PhD, University of Banja Luka, Bosnia and Herzegovina  
**Professor Emina Hadžić**, PhD, University of Sarajevo, Bosnia and Herzegovina  
**Professor Adnan Ibrahimović**, PhD, University of Tuzla, Bosnia and Herzegovina  
**Professor Biljana Šćepanović**, PhD, University of Montenegro, Podgorica, Montenegro  
**Professor Goran Sekulić**, PhD, University of Montenegro, Podgorica, Montenegro  
**Professor Goran Markovski**, PhD, Ss. Cyril and Methodius University, Skopje, North Macedonia  
**Professor Milorad Jovanovski**, PhD, Ss. Cyril and Methodius University, Skopje, North Macedonia  
**Professor Aneta Hristova Popovska**, PhD, Ss. Cyril and Methodius University, Skopje, North Macedonia  
**Associate Professor Aleksandar Radevski**, PhD, Ss. Cyril and Methodius University, Skopje, North Macedonia  
**Professor Vlatko Šešov**, PhD, Institute of Earthquake Engineering and Engineering Seismology, Skopje, North Macedonia  
**Professor Vladan Kuzmanović**, PhD, University of Belgrade, Serbia  
**Professor Vladimir Lojanica**, University of Belgrade, Serbia  
**Professor Srdjan Kolaković**, PhD, University of Novi Sad, Serbia  
**Professor Slaviša Trajković**, PhD, University of Niš, Serbia  
**Research Professor Saša Milijić**, PhD, Institute of Architecture and Urban & Spatial Planning of Serbia (IAUS), Belgrade, Serbia  
**Senior research fellow Sanja Simonović Alfirević**, PhD, IAUS, Belgrade, Serbia  
**Research Professor Nenad Šušić**, PhD, Institute for testing materials (IMS), Belgrade, Serbia  
**Professor Milan Gocić**, PhD, University of Niš, Serbia

□

## ORGANIZING COMMITTEE

### CO-CHAIRS:

**SASA Corresponding Member Vlada Veljković**, PhD, Serbian Academy of Sciences and Arts, Branch in Niš, Serbia  
**Professor Slaviša Trajković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia

### MEMBERS:

**Professor Zoran Bonić**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Professor Dragan Žunić**, PhD, Activities Coordinator in SASA Branch in Niš, Serbia  
**Milan Randjelović**, PhD, CEO, Science Technology Park Niš, Serbia  
**Boban Veličković**, MSc, Deputy CEO, Building Directorate of Serbia  
**Professor Zlatko Zafirovski**, PhD, Faculty of Civil Engineering, Ss. Cyril and Methodius University, Skopje, North Macedonia  
**Professor Miroslav Marjanovic**, PhD, Faculty of Civil Engineering, University of Belgrade, Serbia  
**Professor Igor Pesko**, PhD, Faculty of Technical Sciences, University of Novi Sad, Serbia  
**Senior Research Fellow Božidar Manić**, PhD, Institute of Architecture and Urban & Spatial Planning of Serbia (IAUS), Belgrade, Serbia  
**Professor of Applied Sciences Nenad Stojković**, PhD, Academy of Applied Technical and Educational Studies in Niš, Serbia  
**Associate Research Professor Milan Stojković**, PhD, Institute for Artificial Intelligence of Serbia, Novi Sad, Serbia  
**Professor Snežana Djorić-Veljković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Vuk Milošević**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Assistant Professor Ljiljana Jevremović**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Professor Marina Mijalković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Professor Zoran Grdić**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Nenad Ristić**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Elefterija Zlatanović**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Assistant Professor Miomir Miljković**, PhD, University of Niš, Serbia  
**Associate Professor Žarko Petrović**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Professor Ljiljana Vasilevska**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Professor Danica Stanković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Professor Sonja Kراسić**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Professor Dragan Kostić**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Professor Miomir Vasov**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Aleksandar Milojković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Marko Nikolić**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Assistant Professor Dušan Randelović**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Assistant Professor Radovan Cvetković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Milica Marković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Srdjan Zivković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Milena Dinić-Branković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Ana Momčilović-Petronijević**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia

## LOCAL ORGANIZING TEAM

### CHAIR:

**Professor Zoran Bonić**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia

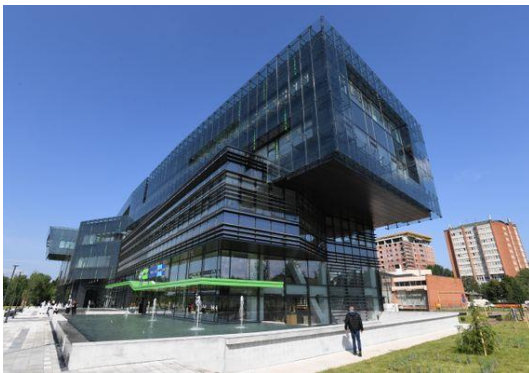
### MEMBERS:

**Associate Professor Vuk Milošević**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Assistant Professor Ljiljana Jevremović**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Professor Snežana Djorić-Veljković**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Associate Professor Nenad Ristić**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Assistant Professor Dušan Randelović**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Teach. Ass. Milica Igić**, PhD, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Teach. Ass. Aleksandar Djordjević**, Faculty of Civil Engineering and Architecture, University of Niš, Serbia  
**Teach. Ass. Nemanja Marinković**, Faculty of Civil Engineering and Architecture, University of Niš, Serbia

## CONFERENCE TOPICS

- ✓ *URBAN AND SPATIAL PLANNING*
- ✓ *PLANNING AND DESIGNING SMART AND RESILIENT CITIES*
- ✓ *URBAN AND ARCHITECTURAL DESIGN - THEORY AND PRACTICE*
- ✓ *ARCHITECTURAL DESIGN AND ANALYSIS*
- ✓ *ARCHITECTURE AND BUILT ENVIRONMENT*
- ✓ *BIOCLIMATIC AND BIOPHILIC ARCHITECTURE*
- ✓ *PRINCIPLES OF ECOLOGICAL DESIGN AND CONSTRUCTION*
- ✓ *BUILT HERITAGE PROTECTION AND MANAGEMENT*
- ✓ *BUILDING RENOVATION AND RECYCLING*
- ✓ *ARCHITECTURAL ENGINEERING*
- ✓ *BUILDING INFORMATION MODELING (BIM)*
- ✓ *STRUCTURAL ENGINEERING*
- ✓ *MATERIALS IN CIVIL ENGINEERING AND ARCHITECTURE*
- ✓ *ENGINEERING MECHANICS*
- ✓ *WATER RESOURCES MANAGEMENT*
- ✓ *HIGHWAY ENGINEERING*
- ✓ *GEOTECHNICAL ENGINEERING*
- ✓ *CONSTRUCTION ENGINEERING AND MANAGEMENT*
- ✓ *PROJECT MANAGEMENT*
- ✓ *CIRCULAR ENGINEERING*
- ✓ *ENTREPRENEURSHIP AND ENGINEERING*
- ✓ *TRANSPORTATION RESEARCH AND DEVELOPMENT*
- ✓ *CLIMATE CHANGE CHALLENGES IN ENGINEERING*
- ✓ *DISASTER RISK MANAGEMENT*

## CONFERENCE VENUE



International Conference

**Synergy of  
Architecture &  
Civil Engineering**

Niš (SERBIA) - Science & Technology Park Niš - September 14-15, 2023

## **PREFACE**

*The primary goal of the SINARG 2023 conference is to present contemporary achievements in the scientific and practical aspects of architecture and civil engineering. The organizers of the conference aimed to facilitate the participation of both national and international professionals in theoretical and experimental research related to the processes of design, project management, construction, and building maintenance within the construction industry.*

*Simultaneously, this scientific conference serves as a platform for exchanging experiences and information regarding innovations and advancements in planning, design, new materials, and construction and reconstruction technologies within the fields of architecture and civil engineering.*

*Therefore, this conference should serve as a forum where experts from civil engineering, architecture, and other related fields have the opportunity to present the results of their research. In that context, conference topics have been carefully selected to provide focus on current issues in the field and encourage productive discussion bringing fresh and original insights and concepts to the forefront.*

*More than 180 paper proposals have been submitted to the conference. A single-blind review process was used to assess the full papers. The reviewers are esteemed scientists holding PhD degrees in the same field as the paper's topic. There are more than 70 reviewers from ten countries who have significantly contributed to the scientific quality of the conference, and their names are printed in the proceedings.*

*A total of 142 full papers have been accepted for publication. Some of the papers have been selected for publication in our journals, with nineteen papers in *Facta Universitatis: Architecture and Civil Engineering* and nine in the *Journal of the Faculty of Civil Engineering and Architecture*. The conference proceedings consist of 114 papers divided into two volumes.*

*The total number of authors and co-authors accepted for publishing at SINARG 2023 exceeds 320. Out of this number, more than 80 authors come from abroad, representing 19 countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Germany, Greece, Hungary, India, Indonesia, Netherlands, North Macedonia, Montenegro, Oman, Poland, Romania, Serbia, Slovakia, Turkey, United Kingdom).*

*The editors express their gratitude to all the authors for their participation and to the reviewers for their valuable comments, which have contributed to the improvement of the original manuscripts and have enhanced the overall quality of the conference..*

## CONTENTS

### **PREFACE**

57. **CLASSIFICATION OF RAILWAY SUPERSTRUCTURE RECONSTRUCTION METHODS** 597  
*JELENA DIMITRIJEVIĆ, ZLATKO ZAFIROVSKI*
58. **COMPARISON OF DAILY AND MONTHLY REFERENCE EVAPOTRANSPIRATION IN AN URBAN AREA** 607  
*MLADEN MILANOVIĆ, SLAVISA TRAJKOVIC, MILAN GOCIC, MARTINA ZELENKOVA, HANY F. ABD-ELHAMID*
59. **EARTHQUAKE RESISTANCE OF PILE FOUNDATIONS** 614  
*BORKO MILADINOVIC, ZVONKO TOMANOVIC*
60. **ANALYSIS OF THE BEARING CAPACITY OF A MASONRY WALL UNDER THE ACTION OF AN EARTHQUAKE THAT HAPPENED IN TURKEY IN 2023** 625  
*FARIS TREŠNJO*
61. **MARKETING SPECIALIZED IN THE FIELD OF CONSTRUCTION AND ARCHITECTURE TO CREATE AN INTERACTIVE RELATIONSHIP IN THE REAL ESTATE MARKET** 636  
*LJILJANA STOŠIĆ MIHAJLOVIĆ, MARIJA MIHAJLOVIĆ*
62. **CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT IN SERBIA** 647  
*IVAN STOJKOVIĆ, PREDRAG STANKOVIĆ, MILICA TRPKOVA*
63. **PREISACH MODEL FOR INNER HYSTERESIS LOOPS OF CYCLICLY LOADED MILD STEEL ELEMENTS** 659  
*PETAR KNEŽEVIĆ, ALEKSANDAR RADAKOVIĆ, NIKOLA VELIMIROVIĆ, ZORAN PEROVIĆ, NENAD STOJKOVIĆ*
64. **THE POSSIBILITY OF IMPROVING THE ARCHITECTURAL DESIGN OF COMMUNAL AND CIRCULATION AREAS IN PRESCHOOLS USING THE SPACE SYNTAX METHOD** 667  
*SOFIJA ICKOVSKI, MILAN TANIĆ*
65. **ARTS AND ARCHITECTURAL COLLABORATIONS IN ATHENS OF THE SIXTIES (60S)** 678  
*DIMITRIS GRIGORIOU*
66. **EXTENDING THE LIFE OF RESIDENTIAL BUILDINGS THROUGH ADAPTATION: A CASE STUDY OF NIŠ, SERBIA** 690  
*BRANISLAVA STOILJKOVIĆ, HRISTINA KRSTIĆ, NATAŠA PETKOVIĆ, VLADANA PETROVIĆ*
67. **RIVER TRAINING WORKS WITH THE AIM OF FLUVIAL PROCESSES CONTROL THROUGH THE SEDIMENT TRANSPORT AND DEFORMATION OF THE RIVER BED ANALYSIS** 701  
*ALEKSANDRA ILIĆ, ILIJA ILIĆ, DRAGAN RADIVOJEVIĆ, BORKO RADIVOJEVIĆ*
68. **ANALYSIS OF THE INTERACTION BETWEEN THE FOUNDATION SLAB AND THE SOIL IN A MULTI-STOREY REINFORCED CONCRETE BUILDING** 713  
*MARIJANA JANIČIJEVIĆ, STEFAN MIHAJLOVIĆ*
69. **EXPLORING THE POSSIBILITY OF CONNECTING THE GAME ENGINE AND GIS AS MEANS OF DECISION SUPPORT IN URBAN PLANNING** 723  
*PETAR VRANIĆ, DUŠAN TATIĆ*
70. **LARGE HOUSING ESTATES IN POST-SOCIALIST PERIOD: DEVELOPMENT STRATEGIES AND PRACTICE** 733  
*JELENA ĐEKIĆ, MILENA DINIĆ BRANKOVIĆ, MILICA LJUBENOVIĆ, MILICA IGIĆ, MIHAILO MITKOVIĆ*
71. **"ERASING" THE BOUNDARY BETWEEN INTERNAL AND EXTERNAL SPACES IN PRESCHOOL FACILITIES** 745  
*ALEKSANDRA RANČIĆ, DANICA STANKOVIĆ, ALEKSANDRA CVETANOVIĆ*
72. **THE WAY OF BEAUTY - ARCHITECTURE AS A QUASI-OBJECT BETWEEN CONSUMPTION AND SUSTAINABILITY** 756  
*MILENA METALKOVA-MARKOVA*
73. **AFFIRMING THE CONCEPT OF CONTINUITY IN THE MODERNIST HERITAGE THROUGH THE NOTION OF BORDER: CASE STUDY OF THE MEANDER BUILDINGS IN NEW BELGRADE'S BLOCK 23** 765  
*VANJA SPASENOVIĆ, BOJANA SIČOVIĆ*
74. **COOPERATION BETWEEN ARCHITECTS AND STRUCTURAL ENGINEERS IN THE DESIGN OF COMPLEX STRUCTURES – THE REVIEW** 777  
*MILOŠ ČOKIĆ, RUŽICA KOVAČEVIĆ, RADOMIR FOLIĆ, NADJA KURTOVIĆ FOLIĆ*



- 
75. **QUANTITATIVE CHARACTERISTICS OF HIGH INTENSITY RAINFALL IN THE VICINITY OF THE CITY OF NIS** 789  
*STEVAN PROHASKA, ALEKSANDRA ILIĆ, OGNJEN PROHASKA, VLADISLAVA BARTOŠ DIVAC*
76. **STABILITY OF COMPRESSED CHORD OF HALF-THROUGH TRUSS GIRDERS IN BRIDGE CONSTRUCTION ACCORDING TO EUROCODE WITH CASE STUDY** 799  
*ALEKSANDAR STOJANOVIĆ, JOVAN ANĐELKOVIĆ*
77. **PUBLIC PARTICIPATION SUPPORTING URBAN SUSTAINABILITY TRANSITION: RECENT EXPERIENCES FROM PLANNING AND GOVERNANCE PRACTICE IN SERBIAN CITIES** 808  
*NATASA ČOLIĆ, MARINA NENKOVIĆ-RIZNIC, MARIJANA PANTIC*
78. **OCCUPATIONAL SAFETY AND HEALTH IN CONSTRUCTION INDUSTRY – CHALLENGES OF MODERN LABOR LEGISLATION AND PRACTICE** 819  
*ALEKSANDRA ILIĆ PETKOVIĆ, IVAN MIJALOVIĆ*
79. **DEFLECTIONS OF BARREL VAULT SHAPED MEMBRANE MODEL UNDER EXTERNAL LOADS** 827  
*VUK MILOŠEVIĆ, DRAGAN KOSTIĆ, MIOMIR VASOV, DUŠAN RANĐELOVIĆ, JANUSZ MARCHWIŃSKI*
80. **BIOPHILIC DESIGN PRINCIPLES IN WORKPLACE** 837  
*STELA SKRIZHOVSKA-KOLEVA*
81. **THE LARGE-SCALE COLLECTIVE HOUSING OF SOCIALIST YUGOSLAVIA – THE INTRODUCTION AND DEVELOPMENT OF A NEW WAY OF CITY LIFE** 846  
*VIOLETA STEFANOVIĆ*
82. **INVESTIGATION OF THE POSSIBILITIES OF USING “BUZZI-SPACE” APPLICATION IN ORDER TO PREDICT REVERBERATION TIME** 855  
*PREDRAG RADOMIROVIĆ*
83. **POSSIBILITIES OF ABSENTEE LEARNING IN ARCHITECTURAL DESIGN** 864  
*NIKOLAY ISTATKOV*
84. **FATIGUE LIFE PREDICTION OF ADHESIVELY BONDED JOINTS BASED ON STIFFNESS DEGRADATION** 875  
*NENAD STOJKOVIĆ, PETAR KNEŽEVIĆ, NIKOLA VELIMIROVIĆ, NEMANJA MARKOVIĆ*
85. **TOWARDS NUMERICAL ARCHITECTURAL ORDER IDENTIFICATION: EXPRESSING CAPITAL MORPHOLOGY BY USING DYNAMICS OF ITS PARAMETERS** 886  
*DJORDJE MITROVIĆ, DJORDJE DJORDJEVIĆ, MIRJANA DEVETAKOVIĆ, GORDANA DJUKANOVIĆ*
86. **SOME SIGNIFICANT ACHIEVEMENTS OF CONCRETE STRUCTURES** 898  
*NADJA KURTOVIĆ FOLIĆ, RADOMIR FOLIĆ, MILOŠ ČOKIĆ*
87. **GEOMETRY AND FORM IN FUNCTION OF INTERIOR SPACE AND OUTER APPEARANCE** 910  
*JOVANA VUKANIĆ, VLADAN NIKOLIĆ, JASMINA TAMBURIĆ, OLIVERA NIKOLIĆ, SANJA SPASIĆ ĐORĐEVIĆ*
88. **HYDROTECHNICAL TUNNELS AT DAMS** 916  
*ZLATKO ZAFIROVSKI, MARIJA PETKOVSKA*
89. **ANALYSIS OF PHASES AND STEPS OF THE ISO 22370 STANDARD IN PLANNING AND DESIGNING SMART AND RESILIENT CITIES** 928  
*ANA STOJANOVIĆ, DEJAN VASOVIĆ*
90. **POTENTIALS OF EPHEMERAL ARCHITECTURE TO ENCOURAGE REUSE AND ADAPTATION OF ABANDONED INDUSTRIAL COMPLEXES** 935  
*DIMITRA JEZDIMIROVIĆ*
91. **DAMAGE FORMS OF STEEL CONSTRUCTIONS** 947  
*MARKO MILOŠEVIĆ, DRAGOSLAV STOJIĆ, SRĐAN ŽIVKOVIĆ*
92. **THE USE OF “GEOTEXTILES” FOR THE PROTECTION OF ARCHAEOLOGICAL SITES WITH MOSAICS** 959  
*ELENA VASIĆ PETROVIĆ*
93. **EVALUATION OF BRIDGE TRAFFIC LOAD MODEL USING B-WIM MEASUREMENTS IN SERBIA** 969  
*GORAN MILUTINOVIĆ, RADE HAJDIN*
94. **ANALYSIS OF THE CONCEPT OF BUILDING INTEGRATED PHOTOVOLTAICS WITH INTEGRATION TO THE ARCHITECTURAL DESIGN** 979  
*VIKTORIJA MANGAROSKA, KOSTA MANGAROSKI*
-

95.	<b><u>THE INTEGRATION OF GREENERY IN ARCHITECTURE AS AN APPROACH TO ROOFTOP EXTENSION</u></b>	<b>991</b>
	<i>IVANA MIŠKELJIN, IGOR MARAŠ</i>	
96.	<b><u>REUSE AND ENVIRONMENTAL IMPACTS OF TREATED DOMESTIC WASTEWATER</u></b>	<b>1002</b>
	<i>MUHAMMED KAMIL ÖDEN, BILGEHAN YABGU HORASAN, CEMALETTIN SARIÇOBAN, ALI ÖZDÖNER</i>	
97.	<b><u>ARCHITECTURAL FORM AND LIBRARY DESIGN</u></b>	<b>1009</b>
	<i>NEVENA PAVLOVIĆ, DANICA STANKOVIĆ</i>	
98.	<b><u>CONTEMPORARY METHODOLOGY OF BANKING DESIGN</u></b>	<b>1020</b>
	<i>ĐURĐINA RANČIĆ, DANICA STANKOVIĆ</i>	
99.	<b><u>STUDIES ON THE IMPACT OF WASTE FOUNDRY SAND ON THE PROPERTIES OF CEMENT COMPOSITES FOR ENVIRONMENT CONCERNS IN OMAN</u></b>	<b>1033</b>
	<i>RATHAN RAJ RAJENDRAN, ALI SAID AHMED MATRAF ALMANJAWI</i>	
100.	<b><u>BULGARIAN PRACTICE AND EXPERIENCE IN DESIGN DEVELOPMENT OF YOUTH CENTRES</u></b>	<b>1044</b>
	<i>BORIANA NOZHAROVA</i>	
101.	<b><u>THE CONSTRUCTION PROJECT EFFICIENCY OF PIER HEAD STRUCTURE DESIGN USING THE HIGH YIELD STRENGTH STEEL</u></b>	<b>1054</b>
	<i>AGUNG FAJARWANTO, ARRY ARYADI, G. AJI SENTOSA, HARRY BUDI PRASETYA, ERI DWI WIBAWA, ANNISA DEWANTI PUTRI, MUHAMMAD ILHAM ADITYA, FARIDZ MOHAMMAD EDRIE</i>	
102.	<b><u>INFLUENCE OF DIFFERENT TYPES OF FIBERS ON PROPERTIES OF CONCRETE</u></b>	<b>1066</b>
	<i>MARKO STOJANOVIĆ, LANA ANTIĆ-ARANĐELOVIĆ KSENIJA JANKOVIĆ, DRAGAN BOJOVIĆ, ZELJKO FLAJS</i>	
103.	<b><u>DEVELOPING THE DATABASE OF WEFEX NEXUS PROJECTS AND CASE STUDIES</u></b>	<b>1073</b>
	<i>ŽARKO VRANJANAC, STEFANIA MUNARETTO, ALEXANDRA SPYROPOULOU, TAMARA RADENOVIĆ, DEJAN VASOVIĆ, SNEŽANA ŽIVKOVIĆ</i>	
104.	<b><u>INFLUENCE OF THERMAL INSULATION POSITION ON CONDENSATION IN THE WALL</u></b>	<b>1079</b>
	<i>ANKA STARČEV-ČURČIN, VESNA BULATOVIĆ, TIANA MILOVIĆ, MILOŠ SEŠLIJA</i>	
105.	<b><u>ENERGY EFFICIENCY OF BUILDINGS IN SERBIA - SOME PERSONAL EXPERIENCES FROM THE PROCESS OF DESIGN AND REALIZATION</u></b>	<b>1087</b>
	<i>ALEKSANDAR RAJČIĆ</i>	
106.	<b><u>ASSESSMENT OF THE QUALITY OF HOUSING STOCK IN BELGRADE ACCORDING TO ENERGY CONSUMPTION</u></b>	<b>1099</b>
	<i>LJILJANA ĐUKANOVIĆ</i>	
107.	<b><u>EFFLUENT QUALITY FROM THE WASTEWATER TREATMENT PLANT LESKOVAC</u></b>	<b>1111</b>
	<i>RASTISLAV TRAJKOVIĆ, MARIJA MILIČEVIĆ, DRAGAN MILIČEVIĆ</i>	
108.	<b><u>RE-VILLAGE ECOLOGICAL EXPERIMENTS IN ARCHITECTURE</u></b>	<b>1121</b>
	<i>ANDREJ JOSIFOVSKI, ANĐELA POSAVEC, STEFAN JANKOVIĆ, JELENA MILOŠEVIĆ</i>	
109.	<b><u>ARCHITECTURE AND TEXTILES - A MILLENNIAL STORY</u></b>	<b>1127</b>
	<i>BEATRICE-GABRIELA JÖGER</i>	
110.	<b><u>SULFATE RESISTANCE OF GEOPOLYMER CONCRETE PRODUCED WITH HAZARDOUS WASTE VITREOUS ENAMEL GENERATED IN THE PRODUCTION PROCESS OF HEATING DEVICES</u></b>	<b>1139</b>
	<i>NENAD RISTIĆ, JELENA BIJELIĆ, DUŠAN GRDIĆ, GORDANA TOPLIČIĆ-ČURČIĆ, ZORAN GRDIĆ</i>	
111.	<b><u>SIGNIFICANCE OF NUMERICAL SIMULATION OF SOIL MEDIA IN SSI ANALYSIS OF FRAMES</u></b>	<b>1147</b>
	<i>KEMAL EDIP, VLATKO SHESHOV, JULIJANA BOJADJIEVA, TONI KITANOVSKI AND DEJAN IVANOVSKI</i>	
112.	<b><u>LANDSLIDE SUSCEPTIBILITY MAPS (LSM) - METHODOLOGY AND APPLICATION IN SPATIAL PLANNING</u></b>	<b>1154</b>
	<i>ADNAN IBRAHIMOVIĆ, KENAN MANDŽIĆ, NEDRETA KIKANOVIĆ, ELVIR BABAJIĆ</i>	
113.	<b><u>APPLICATION OF GIS IN A SYSTEM FOR PLANNING, MANAGEMENT, AND MAINTENANCE OF SEWER NETWORK</u></b>	<b>1166</b>
	<i>NEDRETA KIKANOVIĆ, ELVIR FERHATBEGOVIĆ</i>	
114.	<b><u>THE IMPORTANCE OF THE NEXUS GOVERNANCE FOR ACHIEVING SDGS</u></b>	<b>1178</b>
	<i>TAMARA RAĐENOVIĆ, DEJAN VASOVIĆ, ŽARKO VRANJANAC, SNEŽANA ŽIVKOVIĆ, SLOBODAN MILUTINOVIĆ</i>	

# TOWARDS NUMERICAL ARCHITECTURAL ORDER IDENTIFICATION: EXPRESSING CAPITAL MORPHOLOGY BY USING DYNAMICS OF ITS PARAMETERS

Djordje Mitrović<sup>1</sup>, Djordje Djordjević<sup>2</sup>, Mirjana Devetaković<sup>3</sup>,  
Gordana Djukanović<sup>4</sup>

## Abstract

*Previous subject-related research, that describes stylistic peculiarities of artefacts by taking into account their morphometric/geometric characteristics, explicates the results (used to differentiate them in terms of style they belong to) mainly descriptively – by evaluating the obtained data visually.*

*The narrower aim of this Paper is to explicate the mentioned characteristics numerically/quantitatively by transposing stylistic-wise parameters (descriptors of fractal and non-fractal nature), previously investigated by the actual authors, into the form of dynamics of their values namely explicators. Therefore, the main research questions of this study are both how to express artefact morphology by using dynamics of its parameters and, thus, how to numerically/quantitatively identify architectural style concrete artefact belongs to.*

*To achieve that scientifically, a triplet of capital samples (as the most distinctive elements among artefacts), namely their digital 3D models, are employed per each fundamental classical architectural order (Doric, Ionic, and Corinthian). The subject of this Paper is to establish relevant morphometric/geometric indicators not only in the form of explicators mentioned above, but qualifiers too, enabling so: to numerically express capital morphology, namely to quantitatively estimate levels of intra-similarity of capitals assumed to belong to the same order, and inter-dissimilarity of those assumed to belong to different ones. Both types of the established indicators refer to capital contours which are positioned in mutually equidistant transverse section planes (defined per each chosen capital sample of each of the analysed orders).*

*The wider research aim refers to both: (a) a possibility to numerically/quantitatively identify order a concrete fragment of capital/artefact belongs to in terms of recognising it computationally (as confidently as possible from the mathematical probability point of view), and (b) to perform morphology-wise capital/artefact segmentation.*

*Presented innovative methodology brings up a more reliable possibility to identify architectural order “stylistically unknown capital” belongs to – by using a newly introduced indicator (in the form of dynamics) to express its morphology numerically/quantitatively. Future research will be dealt with software-wise automation of stylistic decoding steps (rough capital classification and order-belonging estimation).*

**Key words:** *dynamics, fractal object, numerical stylistic analysis, morphology-wise parameters, classical architectural order capital*

---

<sup>1</sup> PhD Student, Teaching Assistant, University of Belgrade, Faculty of Architecture, djordje.mitrovic@arh.bg.ac.rs

<sup>2</sup> PhD, Associate Professor, University of Belgrade, Faculty of Architecture, djordje@arh.bg.ac.rs

<sup>3</sup> PhD, Assistant Professor, University of Belgrade, Faculty of Architecture, mirjana.devetakovic@arh.bg.ac.rs

<sup>4</sup> PhD, Associate Professor, University of Belgrade, Faculty of Forestry, gordana.djukanovic@sfb.bg.ac.rs

## 1. INTRODUCTION

To express artefact morphology in the scientifically sustainable way, various parameters of different nature have to be employed. More suitable ones are of fractal nature, expressed by the usage of fractal geometry, due to the fact that its principles can adequately explicate morphology in a whole. In the domains of architecture and urbanism, previous research is predominantly carried out in the fields of design, construction, heritage preservation, human-building interactions and others ([1], [2], [3], [4], [5], [6], [7]).

Additionally, mentioned fractal approach is capable of characterising artefacts geometric features mathematically regarding style they belong to [8]. But, especially in the case of classical architectural orders, a specific newly investigated methodology is developed to qualify and classify belonging capitals as well as to identify/recognise such orders stylistically (by taking into account their morphometric/geometric characteristics, explicating the results mainly descriptively – by evaluating the obtained data visually) [9].

Therefore, the narrower aim of this Paper is to explicate the mentioned characteristics numerically/quantitatively by transposing already introduced stylistic-wise parameters (descriptors) [9] into the form of dynamics of their values (named “explicators”). The main research questions of this study are both how to express capital morphology by using dynamics of its parameters and, thus, how to numerically/quantitatively identify architectural order concrete capital belongs to.

The subject of this Paper is to establish relevant morphometric/geometric indicators in the form of explicators and qualifiers, enabling so to numerically express capital morphology, namely to quantitatively estimate levels of intra-similarity of capitals assumed to belong to the same order, and inter-dissimilarity of those assumed to belong to different ones. Indicators refer to corresponding/ descriptors (inherited from the previous subject-related research conducted by the same authors [9]) obtained by processing capital contours which are positioned in mutually equidistant transverse section planes (related to each of the chosen capitals, namely their digital 3D models).

The wider research aim refers to both: (a) a possibility to numerically/quantitatively identify order a concrete fragment of capital belongs to in terms of recognising it computationally (as confidently as possible from the mathematical probability point of view), and (b) to perform morphology-wise capital segmentation (as a precondition of semantic one) – by employing artificial intelligence in terms of machine learning, primarily [10], [11].

## 2. METHODOLOGY

In order to reach the aims tasked, the main methodology principles are retrieved from the previous research [9], including the definition of indicators (descriptors and qualifiers) and relevant outputs obtained (descriptors values). However, so as the obtained results to be numerically/quantitatively explicable as much as possible, and thus morphometric changes described by trendlines easily detectable, the applied methodology is slightly “tuned”. Consequently, descriptor trendlines are substituted in this research with those of explicators, expressed by dynamics of values of corresponding descriptors. Bearing in mind the fact that the exact spatial positioning

(by using an adequate polar coordinate system) of morphology-wise excesses (morphometric marks of capitals of concrete order) is not considered here from the Paper topic point of view as well as the fact that capital contours from the set which refers to mutually equiangular radial section planes are not “informative” enough regarding the same reason, set of contours of transverse slicing is used here only (unlike it is a case in [9], where both of mentioned sets of contours are processed on an equal footing).

Indicators mentioned in Section 1. are expressed by both: several explicators of fractal and non-fractal nature (as an auxiliary one), and several corresponding qualifiers which are represented by arithmetically averaged values of analysed explicators – expressing so their global “from-section-to-section” changing rule. The nature of the established explicators and qualifiers are broadly explained in Sub-section 2.2.2.

## **2.1. Starting considerations**

To draw scientifically acceptable conclusions, prerequisites and constraints listed in [9] are to be satisfied as mandatory (Morphometry/Geometry-related and ImageAnalysis-related ones).

## **2.2. Methodology setup**

### **2.2.1. Samples selection**

To elaborate on a sustainability of the established capital qualification, capital classification, and numerical/quantitative order identification criteria as well as a validity of defined principles of the aim-related methodology, three representatives (hereinafter: “triplet”) per each fundamental classical architectural order are used (Doric, Ionic, and Corinthian). For a more detailed explanation of previously mentioned selection criteria, one can consult corresponding methodology setup principles described in [9].

### **2.2.2. Indicators definition**

According to the purpose of this research, two types of explicators are defined: the main one – represented by dynamics of descriptors of fractal nature (related to the distribution of (multi)fractal dimensions of capital contours located in each of its transverse section planes – expressed by a unitless value), and the auxiliary one – represented by dynamics of descriptors of non-fractal nature (related to the distribution of areas bounded by the previously generated corresponding sets of contours – expressed by square metres). The auxiliary type of explicators is foreseen due to the same reasons as those of corresponding control descriptors [9]. Consistent with the fundamental meaning of the term “dynamics” (describing it as a changing rate or variation level between two neighbouring values of the same nature (namely, of descriptors inherited from [9]) divided by the adopted unit step of that variation (hereinafter: “AUS”, namely, a distance between two consecutive section planes), following explicators are introduced: FractalExplicatorTransverse (hereinafter: “FET”), and AreaExplicatorTransverse (hereinafter: “AET”).

FET describes a changing rate of fractal-wise descriptor values (FDTs inherited from [9]) along the transverse slicing direction, namely, a variation level between each two consecutive such values divided by AUS of that variation. AET describes

a changing rate of non-fractal-wise descriptor values (ADTs also inherited from [9]) along the transverse slicing direction too, namely, a variation level between each two consecutive such values divided by AUS of that variation.

As in [9], two types of qualifiers are defined, as well: the first one which relates to arithmetically averaged values of explicators of fractal nature, and the second one which relates to arithmetically averaged values of explicators of non-fractal nature – both obtained separately for each triplet of contours defined by section planes of the same ordinal number, namely of the same slicing position in the corresponding triplet of capital samples of the same order (hereinafter: “1st”, “2nd”, and “3rd” sample).

Those types are named in this research as follows: FractalMeanTransverse (hereinafter: “FQT”), and AreaMeanTransverse (hereinafter: “AQT”). Having in mind the previously mentioned explicators typology as well as the fact that qualifiers are derived from, it is obvious that the firstly listed qualifier is also the main one, while the other one is the auxiliary.

### 2.2.3. Quantifiers definition

To achieve data-driven order identification/recognition (based on previously introduced indicators, namely explicators and qualifiers derived from), several quantifiers related to the desired number of AUSs (which approximately<sup>5</sup> correspond to capital canonical zones<sup>6</sup> they refer to) ought to be introduced. Ones, generally declared the most important, are following: (a) Number of Peaks<sup>7</sup>/Valleys<sup>8</sup>, Their Extreme Values, and Distances between Those Extremes Expressed by Number of AUSs, (b) Density of Peaks/Valleys and Their Extreme Values, (c) Intervals between Each Two Consecutive Peaks/Valleys and Their Extreme Values, and (d) Amplitudes of Each Neighbouring Peak-Valley Pair, Their Extreme Values, and Distances between Those Extremes Expressed by Number of AUSs.

A number of the aforementioned capital canonical zones (signed here in Roman numerals (I, II,...)) vary from order to order as it is shown in Figure 1.



*Figure 1. Marked Capital Canonical Zones of Doric, Ionic, and Corinthian Orders (from left to right) – Signed in Roman Numerals*

<sup>5</sup> Proportion rules imply that the heights of capital canonical zones contain a number of AUSs which is not always an integer.

<sup>6</sup> Canonical zone of capital of concrete order is a segment of its mass whose height is defined with respect to the overall capital height according to corresponding proportion rules [12], [13].

<sup>7</sup> Peak is the value of indicator that refers to the case when behaviour of its change along the applied slicing direction is characterised by an increase-to-decrease transition.

<sup>8</sup> Valley is the value of indicator that refers to the case when behaviour of its change along the applied slicing direction is characterised by the decrease-to-increase transition.

Doric capitals generally consist of three visually recognisable morphology-wise zones, while Ionic and Corinthian ones consist of four such zones.

Bearing in mind the quantifiers listed above, due to the limited number of pages, Number of Peaks/Valleys are analysed only. Two classes of chosen quantifier are introduced: Number-of-Peak Quantifier (hereinafter: "NOP Qnt"), Number-of-Valley Quantifier (hereinafter: "NOV Qnt").

### 3. INDICATORS AND QUANTIFIERS OBTAINING

#### 3.1. Explicators calculating

According to the FET/AET definition (stated in Sub-subsection 2.2.2.), based on corresponding FDT/ADT descriptor values inherited from [9], with respect to equation (1)/(2), explicators calculation is performed by the usage of Excel.

$$Kth FET_{(i \rightarrow (i+1))} = (Kth FDT_{(i+1)} - Kth FDT_{(i)}) / AUS, i=(1, n-1), K=(1, 2, 3)$$

where "n" is the total number of transverse section planes,  
while "K" is the ordinal number of concrete capital sample (1)

$$Kth AET_{(i \rightarrow (i+1))} = (Kth ADT_{(i+1)} - Kth ADT_{(i)}) / AUS, i=(1, n-1), K=(1, 2, 3)$$

where "n" is the total number of transverse section planes,  
while "K" is the ordinal number of concrete capital sample (2)

#### 3.2. Qualifiers calculating

According to the FQT/AQT definition (stated in Sub-subsection 2.2.2.), based on each triplet of corresponding previously obtained FET/AET explicators, with respect to equation (3)/(4), qualifiers calculation is also performed by the usage of Excel.

$$FQT_{(i \rightarrow (i+1))} = (1st FET_{(i \rightarrow (i+1))} + 2nd FET_{(i \rightarrow (i+1))} + 3rd FET_{(i \rightarrow (i+1))}) / 3,$$

$i=(1, n-1)$ , where "n" is the total number of transverse section planes (3)

$$AQT_{(i \rightarrow (i+1))} = (1st AET_{(i \rightarrow (i+1))} + 2nd AET_{(i \rightarrow (i+1))} + 3rd AET_{(i \rightarrow (i+1))}) / 3,$$

$i=(1, n-1)$ , where "n" is the total number of transverse section planes (4)

#### 3.3. Quantifiers calculating

According to the NOP Qnt/NOV Qnt definition (stated in Sub-subsection 2.2.3.), based on each triplet of corresponding previously obtained FET/AET explicators namely on each FQT/AQT qualifiers derived from, with respect to equation (5)/(6) namely (7)/(8), quantifiers calculation is performed by the usage of Excel – per each capital canonical zone, separately.

$$Kth NOP Qnt (FET) = Kth NOP Qnt (FET)_I + Kth NOP Qnt (FET)_{II} + \dots,$$

$$Kth NOP Qnt (AET) = Kth NOP Qnt (AET)_I + Kth NOP Qnt (AET)_{II} + \dots,$$

$K=(1, 2, 3)$ , where "K" is the ordinal number of concrete capital sample,  
while "I, II,..." are ordinal numbers of canonical zones of Kth capital sample (5)

$$Kth NOV Qnt (FET) = Kth NOV Qnt (FET)_I + Kth NOV Qnt (FET)_{II} + \dots,$$

$$Kth\ NOV\ Qnt\ (AET) = Kth\ NOV\ Qnt\ (AET)\_I + Kth\ NOV\ Qnt\ (AET)\_{II} + \dots,$$

$K=(1, 2, 3)$ , where “K” is the ordinal number of concrete capital sample, while “I, II,...” are ordinal numbers of canonical zones of Kth capital sample (6)

$$NOP\ Qnt\ (FQT) = NOP\ Qnt\ (FQT)\_I + NOP\ Qnt\ (FQT)\_{II} + \dots,$$

$$NOP\ Qnt\ (AQT) = NOP\ Qnt\ (AQT)\_I + NOP\ Qnt\ (AQT)\_{II} + \dots,$$

while “I, II,...” are ordinal numbers of canonical zones of concrete order (7)

$$NOV\ Qnt\ (FQT) = NOV\ Qnt\ (FQT)\_I + NOV\ Qnt\ (FQT)\_{II} + \dots,$$

$$NOV\ Qnt\ (AQT) = NOV\ Qnt\ (AQT)\_I + NOV\ Qnt\ (AQT)\_{II} + \dots,$$

while “I, II,...” are ordinal numbers of canonical zones of concrete order (8)

### 4. RESULTS

The results are differently represented with respect to the fact whether they refer to the obtained values of indicators or quantifiers. So, first ones are in the form of six charts (3x2=6). Charts 1, 3, and 5. show transverse-wise trendlines triplets of explicators of both defined types (fractal and non-fractal), related to the triplet of capital samples of the same order. Charts 2, 4, and 6. show transverse-wise trendlines of qualifiers of the same previously mentioned types. Each qualifier trendline (as mean one) substitutes the corresponding triplet of explicator trendlines by “averaging” it (hereinafter: “Dor FQT”, “Ion FQT”, “Cor FQT” and “Dor AQT”, “Ion AQT”, “Cor AQT”).

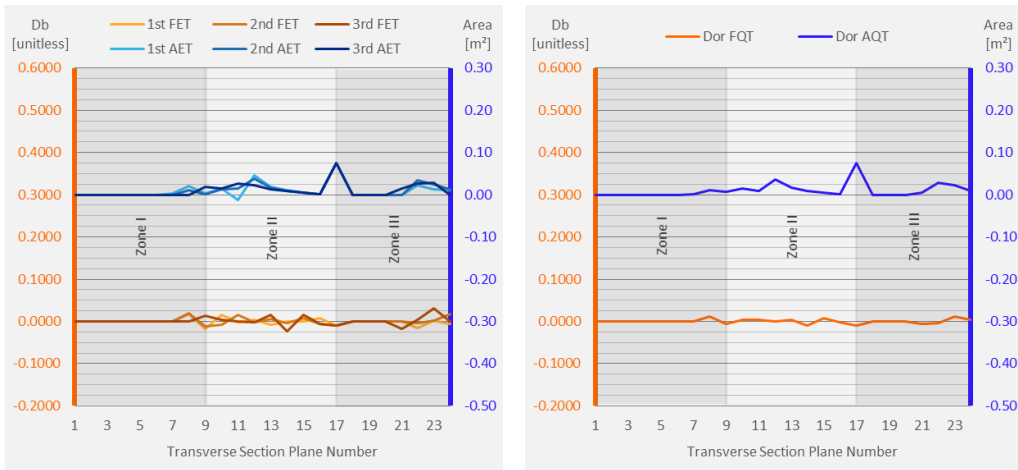
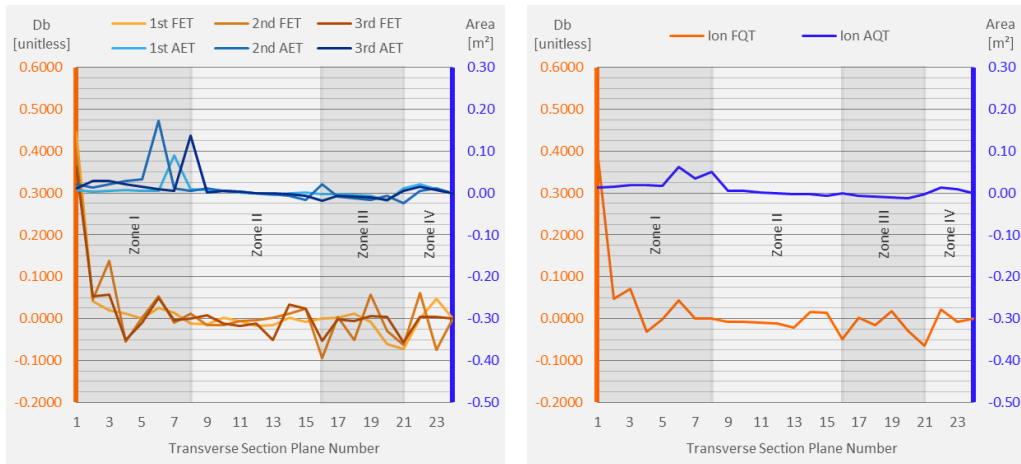


Chart 1. (left) Intra-order “Doric” Similarity: Transverse-wise Explicator Trendlines Related to the Triplet of Corresponding Capital Samples

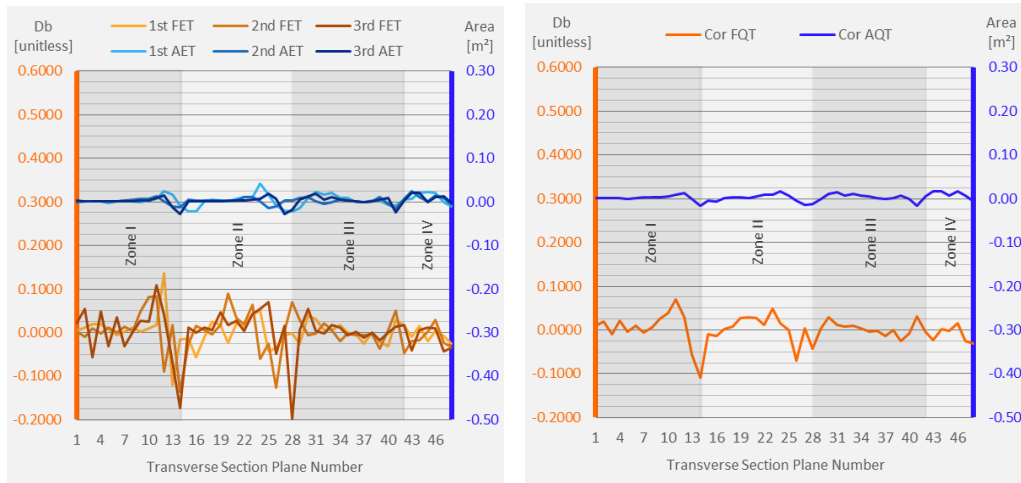
Chart 2. (right) Transverse-wise Fractal and Non-fractal Qualifier Trendlines That Substitute Triplets of Corresponding Doric Explicator Trendlines





**Chart 3. (left) Intra-order “Ionic” Similarity: Transverse-wise Explicator Trendlines Related to the Triplet of Corresponding Capital Samples**

**Chart 4. (right) Transverse-wise Fractal and Non-fractal Qualifier Trendlines That Substitute Triplets of Corresponding Ionic Explicator Trendlines**



**Chart 5. (left) Intra-order “Corinthian” Similarity: Transverse-wise Explicator Trendlines Related to the Triplet of Corresponding Capital Samples**

**Chart 6. (right) Transverse-wise Fractal and Non-fractal Qualifier Trendlines That Substitute Triplets of Corresponding Corinthian Explicator Trendlines**

The quantifiers-related results are represented in the form of three tables (2+1=3) and variety of doughnut-charts derived from the corresponding filled-in results. Table 1. and Table 2. contain values of indicator-wise quantifiers regarding analysed orders and canonical zones of corresponding capital samples. Table 3. represents values of qualifiers numerical thresholds of fractal and non-fractal nature that relate to one of the examined orders only – the Corinthian one (due to its morphology-wise complexity – the greatest among analysed). Those thresholds are represented by minimal and maximal values of explicator-wise quantifiers and threshold means (qualifier-wise quantifiers) calculated by averaging.

Table 1. Intra-order Similarity: Values of Explicator-wise Quantifiers Regarding Analysed Orders and Canonical Zones of Corresponding Capital Samples

Table 1.				Canonical Zones of Selected Capital Samples											
				1st				2nd				3rd			
				I	II	III	IV	I	II	III	IV	I	II	III	IV
Analysed Explicator-wise Quantifiers: Number of Peaks / Valleys	NOP Qnt	FET	Dor	1	3	2	/	1	3	1	/	1	2	2	/
			Ion	1	2	1	1	3	1	2	1	2	3	2	1
			Cor	4	4	4	2	5	5	4	1	5	6	5	1
		AET	Dor	1	3	1	/	1	2	1	/	1	2	1	/
			Ion	2	1	0	1	1	2	1	1	2	1	1	1
			Cor	2	2	3	1	1	3	3	2	1	1	3	2
	NOV Qnt	FET	Dor	1	3	1	/	1	3	1	/	0	3	1	/
			Ion	1	3	1	0	3	2	2	1	3	3	2	0
			Cor	3	4	4	2	6	4	5	0	5	6	4	2
		AET	Dor	1	2	1	/	1	1	1	/	0	2	1	/
			Ion	2	1	1	0	2	1	2	0	1	2	1	0
			Cor	2	3	3	0	1	3	3	1	2	1	3	1

Table 2. (left) Inter-order Dissimilarity: Values of Qualifier-wise Quantifiers Regarding Analysed Orders and Corresponding Capital Canonical Zones

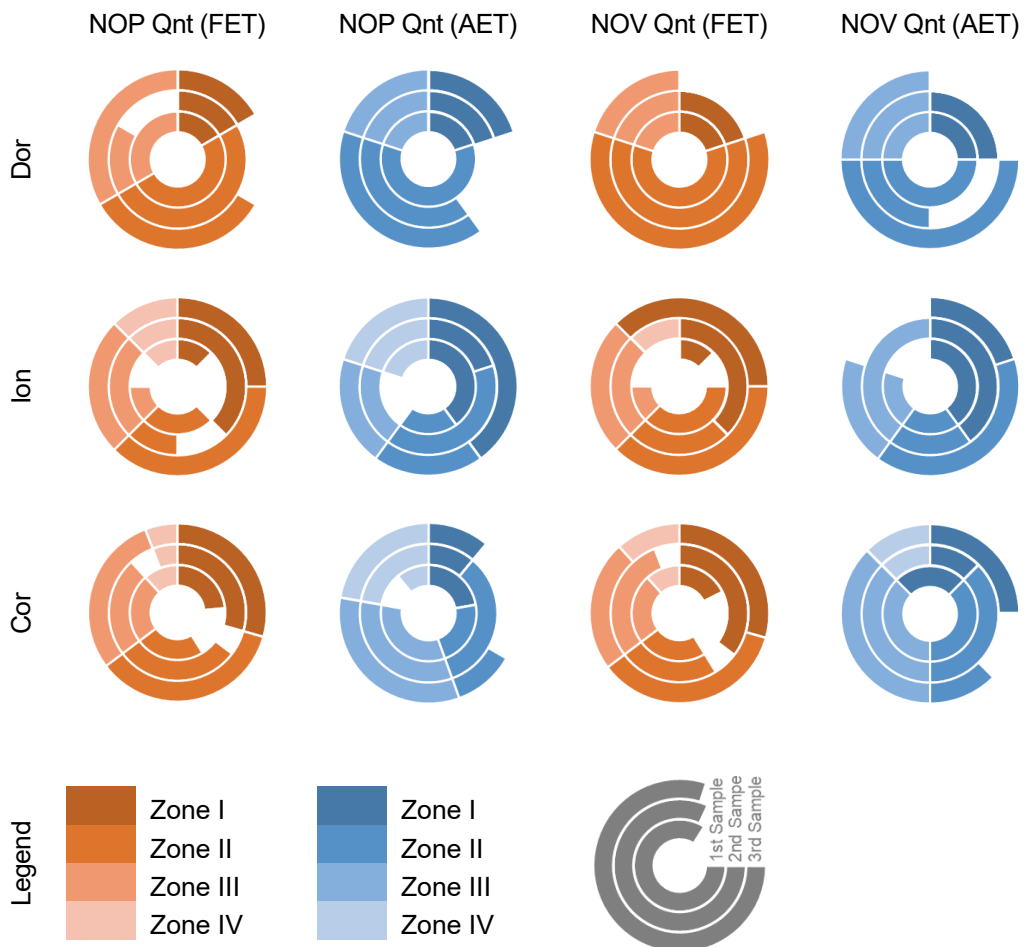
Table 3. (right) Corinthian Order Identification/Recognition: Values of its Qualifier-wise Quantifiers and Corresponding Thresholds (Min, Max) Related to Each Canonical Zone

Table 2.				Canonical Zones of All Analysed Orders			
				I	II	III	IV
Analysed Qualifier-wise Quantifiers: Number of Peaks / Valleys	NOP Qnt	FQT	Dor	1	3	2	/
			Ion	3	1	2	1
			Cor	4	4	5	2
		AQT	Dor	1	3	1	/
			Ion	3	1	0	1
			Cor	2	3	3	2
	NOV Qnt	FQT	Dor	1	3	1	/
			Ion	3	2	2	1
			Cor	4	4	4	2
		AQT	Dor	1	2	1	/
			Ion	2	1	1	0
			Cor	2	3	3	1

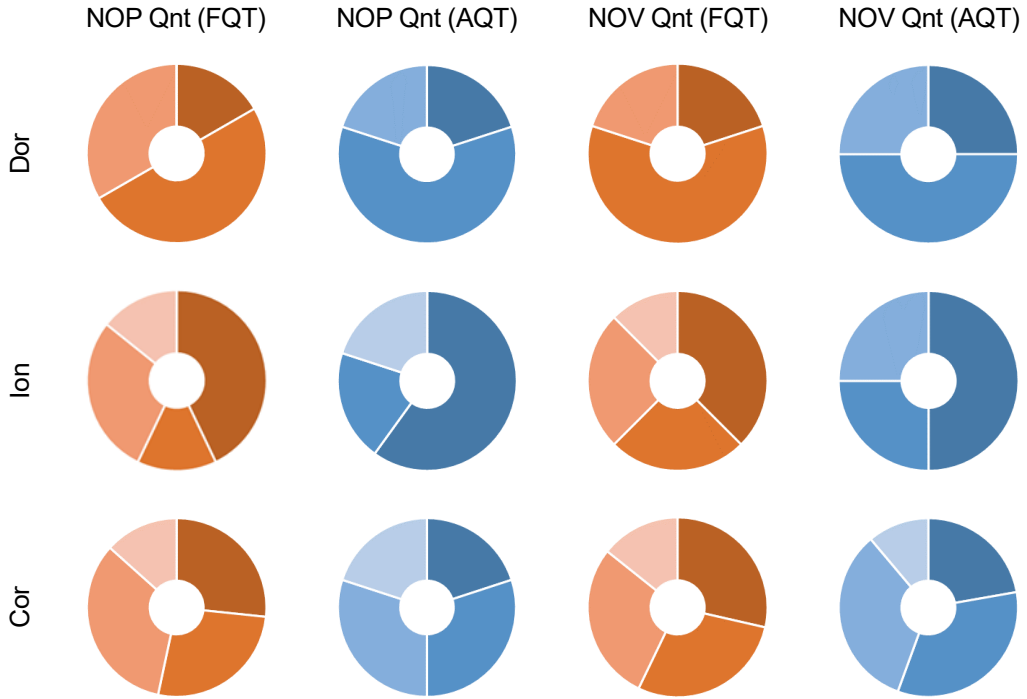
Table 3.			Canonical Zones of Corinthian Order				
			I	II	III	IV	
NOP Qnt	FET	Min	4	4	4	1	
	FQT	Cor	4	4	5	2	
	FET	Max	5	6	5	2	
	FET	Min	1	1	3	1	
	FQT	Cor	2	3	3	2	
	FET	Max	2	3	3	2	
	NOV Qnt	FET	Min	3	4	4	0
		FQT	Cor	4	4	4	2
		FET	Max	6	6	5	2
FET		Min	1	1	3	0	
FQT		Cor	2	3	3	1	
FET		Max	2	3	3	1	

Because of the facts that both capital heights differ from order to order and quantifiers values (which relate to the concrete canonical zone) might vary from sample to sample, to cross-reference the obtained results as reliably as possible, their relative values (calculated based on “absolute counting”) are only compared. Consistent with the fundamental meaning of the term “relative”, a percentage abundance of the analysed quantifiers values related to the concrete canonical zone is to be understood here with respect to their overall number that refers to the capital in whole. Given that the behaviour of trendlines shown in Charts 1, 3, and 5, namely, in Charts 2, 4, and 6 is described by explicators which are functionally dependent on descriptors inherited from [9] (as obtained from them arithmetically), namely, by qualifiers derived from corresponding explicators (by averaging them), the charts mentioned above (that demonstrate an intra-order similarity, namely, an inter-order dissimilarity as identically as those already elaborated in [9]) will not be discussed here, but only behaviours of the researched quantifiers read out from created doughnut-charts (Doughnut-charts 1, 2, and 3).

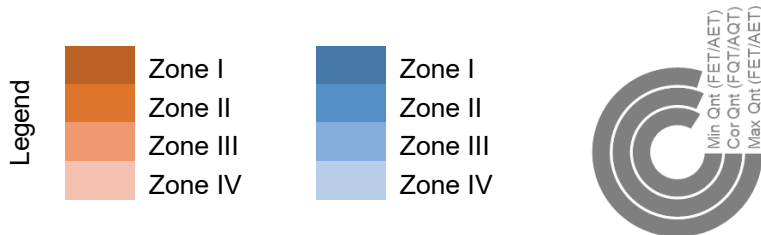
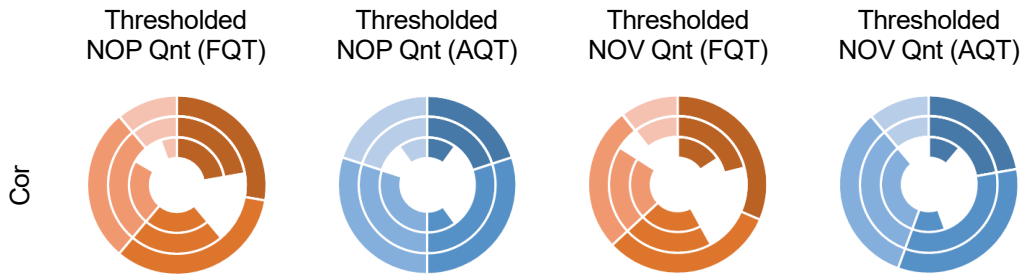
*Doughnut-charts 1. Percentage Abundance of Fractal and Non-fractal Explicator-wise Quantifiers for Doric, Ionic, and Corinthian Order with Regard to Analysed Triplets of Capital Samples and Their Corresponding Canonical Zones*



*Doughnut-charts 2. Percentage Abundance of Fractal and Non-fractal Qualifier-wise Quantifiers Regarding Analysed Doric, Ionic, and Corinthian Order and Corresponding Capital Canonical Zones*



*Doughnut-charts 3. Corinthian Order Identification/Recognition: Percentage Abundance of its Fractal and Non-fractal Qualifier-wise Quantifiers Thresholded by Corresponding Min and Max Percentage Abundances of Explicator-wise Quantifiers Regarding Capital Canonical Zones*



## 5. DISCUSSION AND CONCLUSION

Doughnut-charts 1. Mutually similar behavior of the explicator-wise quantifiers of both types (fractal: orange coloured and non-fractal: blue coloured), and of both classes (NOP and NOV) among the analysed capital samples from the same triplet can be declared almost identical when doughnut rings occupancy namely proximity of sizes<sup>9</sup> of their slices which relate to the same zone are pretty balanced<sup>10</sup>, confirming so intra-order similarity. Slight deviations of doughnut rings occupancy that relate to some of the samples, regardless of orders they belong to (represented by certain blank parts of corresponding rings), could be caused by the following issues: either because of the used 3D models inadequacy (when ones do not conform with the originals from morphology-wise point of view) or because of morphometric non-compliance with strict canonicity.

Doughnut-charts 2. The more similar behaviour of the qualifier-wise quantifiers of the same order and class is (regardless of their type), the greater proximity of sizes of doughnut slices<sup>11</sup> will be, providing so more detectable inter-order dissimilarity. Even though doughnuts of the same class and type related to different orders might seem mutually almost identical (for example: lon NOV Qnt (FQT) and Cor NOV Qnt (FQT)), corresponding doughnuts of the remaining analysed class and/or type do answer whether those quantifiers could be declared members of the same or mutually different orders. It is obvious that the larger number of analysed capitals (representative samples) is, the more accurate sizes of doughnut slices and thus their intra-doughnut distribution (as well as the more reliably inter-order dissimilarity estimation) will be. In that case, as well, it is possible to estimate whether that distribution can be declared acceptable from the statistical probability point of view, by using previously defined relevant thresholds (tolerance).

Doughnut-charts 3. For the reason explained in Section 4., Doughnut-charts 3. are created only – based on data shown in Table 3. By observing containing doughnuts, it is obvious that corresponding “Corinthian” qualifier-wise quantifiers (whose canonical zone-related values are represented by sizes of the middle-ring-slices) belong to the corresponding (zone-related) tolerance ranges (defined by related Min (sizes of the inner-ring-slices) and Max thresholds (sizes of the outer-ring-slices)). Based on the usage of that stylistically known capital, satisfied mentioned condition (being conformed to the acceptable tolerance range) confirms scientific sustainability of the established approach.

It can be concluded that the presented innovative methodology (developed from [9] and slightly “tuned”) brings a more reliable possibility to identify architectural order “stylistically unknown capital” belongs to – by using a newly introduced indicator (in the form of dynamics) to express its morphology numerically/quantitatively. Future research will be dealt with software-wise automation of stylistic decoding steps (rough capital classification and order-belonging estimation).

<sup>9</sup> Size of the ring slice (which refers to the concrete canonical zone of the particular capital sample from the analysed triplet of samples) is a term related to the value of corresponding explicator-wise quantifier. (NOP Qnt (FET/AET)/NOV Qnt (FET/AET))

<sup>10</sup> Balanced occupancy of doughnut rings refers to the approximate “equality” of sizes of belonging slices related to the same capital canonical zone of the concrete order. Term “equality” implies the usage of previously calculated probabilistically acceptable thresholds (tolerance).

<sup>11</sup> Size of the doughnut slice (which refers to the particular canonical zone of triplet of capital samples of the concrete order – represented by that slice) is a term related to the value of corresponding qualifier-wise quantifier (NOP Qnt (FQT/AQT)/NOV Qnt (FQT/AQT))

## ACKNOWLEDGMENTS

This investigation is performed at the University of Belgrade – Faculty of Architecture, within the “Laboratory for Research, Valorisation, Conservation and Presentation of Cultural Heritage”, founded and financed by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant number 451-03-47/2023-01/200090.

## REFERENCES

- [1] Yamu Claudia van der Laag, Frankhauser Pierre: **A multi-scale (multi-fractal) approach for a systemic planning strategy from a regional to an architectural scale**. *15th International Conference on Urban Planning, Regional Development and Information Society 2010*, Vienna, 17-26, 2010.
- [2] Athanasiou Apostolos, Ebrahimkhanlou Arvin, Zaborac Jarrod, Hrynyk Trevor, Salamone Salvatore: **A machine learning approach based on multifractal features for crack assessment of reinforced concrete shells**. *Computer-Aided Civil and Infrastructure Engineering*, Vol. 35, No. 6, 565–578, 2020.
- [3] Carpinteri Andrea, Spagnoli Andrea, Vantadori Sabrina: **A multifractal analysis of fatigue crack growth and its application to concrete**. *Engineering Fracture Mechanics*, Vol. 77, No. 6, 974–984, 2010.
- [4] Ji Hui, Yang Xiong, Ling Haibin, Xu Yong: **Wavelet domain multifractal analysis for static and dynamic texture classification**. *IEEE Transactions on Image Processing*, Vol. 22, No. 1, 286–299, 2013.
- [5] Devetaković Mirjana, Petruševski Ivana, Ćirović Ivana, Petruševski Ljiljana: **Fractal parametric models of urban spaces**. *Tehnicki Vjesnik*. Vol. 22, No. 6, 1547-1552, 2015.
- [6] Ćirović Ivana: **Random curds as mathematical models of fractal rhythm in architecture**. *Spatium*. Vol. 1, No. 31, 79-84, 2014.
- [7] Đorđević Đorđe, Ćirović Ivana: **Visual complexity of fractal rhythm**. *11th International Scientific Conference “Science and Higher Education in Function of Sustainable Development”*. Mečavnik-Drvengrad, Užice, 23-29, 2019.
- [8] Capo Daniele: **The fractal nature of the architectural orders**. *Nexus Network Journal*, Vol. 6, No. 1, 30–40, 2004.
- [9] Mitrović Djordje, Djordjević Djordje, Devetaković Mirjana, Djukanović Gordana: **Encoding/decoding capitals of classical architectural orders by using fractal geometry: Establishing methodology**. *9th International Scientific Conference on Geometry and Graphics, MoNGeometrija 2023*, Novi Sad, 153-167, 2023.
- [10] Diara Filippo, Rinaudo Fulvio: **IFC Classification for FOSS HBIM: Open issues and a schema proposal for cultural heritage assets**. *Applied Sciences*, Vol. 10, No. 23, 8320, 2020.
- [11] Quattrini Ramona, Carlo Battini, Mammoli Raissa: **HBIM to VR. semantic awareness and data enrichment interoperability for parametric libraries of historical architecture**, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2, 937–943, 2018.
- [12] Vitruvius Pollio Marcus: **Deset knjiga o arhitekturi = De architectura libri decem** (M.Lopac, Trans.; R.Jadrešin Milić, Ed.). *Orion art*, Beograd, 2014.
- [13] Chitham Robert: **The Classical Orders of Architecture** (2nd ed.). *Routledge*, London, 2005.

CIP - Каталогизација у публикацији  
Народна библиотека Србије, Београд

624(082)  
72(082)

**INTERNATIONAL Conference Synergy of Architecture & Civil Engineering (2023 ; Niš)**

Proceedings [of] The International Conference Synergy of Architecture & Civil Engineering, SINARG 2023, Niš (Serbia), September 14-15, 2023. Vol. 2 / [editors Slaviša Trajković, Vuk Milošević] ; [organized by University of Niš, Faculty of Civil Engineering and Architecture [and] Serbian Academy of Sciences and Arts - Branch in Niš [and] Serbian Academy of Sciences and Arts - Department of Technical Sciences]. - Niš : University, Faculty of Civil Engineering and Architecture : SASA, Branch in Niš, 2023 (Niš : Grafika Galeb). - [12] str., str. 597-1187 : ilustr. ; 24 cm

Tiraž 100. - Str. [9]: Preface / Editors. - Bibliografija uz svaki rad.

ISBN 978-86-88601-81-8  
ISBN 978-86-88601-82-5 (niz)

а) Грађевинарство -- Зборници б) Архитектура – Зборници

COBISS.SR-ID 123837961