



UCG

Univerzitet Crne Gore



UNIVERSITY OF MONTENEGRO  
FACULTY OF CIVIL ENGINEERING

THE EIGHTH INTERNATIONAL CONFERENCE  
CIVIL ENGINEERING - SCIENCE & PRACTICE

**GNP 2022 PROCEEDINGS**



Kolašin, March 2022





**UNIVERSITY OF MONTENEGRO**



**FACULTY OF CIVIL ENGINEERING**

**THE EIGHTH INTERNATIONAL CONFERENCE  
CIVIL ENGINEERING - SCIENCE & PRACTICE**



**GNP 2022 PROCEEDINGS**

**KOLAŠIN, 8-12 MARCH 2022**

ISBN 978-86-82707-35-6

## GNP 2022 PROCEEDINGS

- Publisher: **UNIVERSITY OF MONTENEGRO  
FACULTY OF CIVIL ENGINEERING**
- For Publisher: **Prof. Marina Rakočević, Dr-Ing.**
- Editors-in-Chief: **Prof. Marina Rakočević, Dr-Ing.  
Assoc. Prof. Biljana Šćepanović, Dr-Ing.**
- Editorial board: **Prof. Marina Rakočević, Dr-Ing.  
Prof. Miloš Knežević, Dr-Ing.  
Assoc. Prof. Biljana Šćepanović, Dr-Ing.  
Assoc. Prof. Olga Mijušković, Dr-Ing.  
Assist. Prof. Ivana Ćipranić, Dr-Ing.  
Assist. Prof. Marija Jevrić, Dr-Ing.  
Mladen Gogić, MSc, Dipl. Ing.  
Boris Jevrić, Dipl. Ing.**
- Technical editing: **Boris Jevrić, Dipl. Ing.**
- Cover photo by: **Ilija Perić**
- Printing: **ARTGRAFIKA D.O.O.**
- Number of copies: **350**

CIP - Каталогизација у публикацији  
Национална библиотека Црне Горе, Цетиње

ISBN 978-86-82707-35-6  
COBISS.CG-ID 21036292

ISBN 978-86-82707-35-6



9 788682 707356 >



# **GNP 2022 SPONSORS**

## **Co-Organiser of the Conference**

ENGINEERS CHAMBER OF MONTENEGRO, CIVIL ENGINEERS CHAMBER  
Podgorica, Montenegro

## **Gold Sponsor**

CHINA ROAD AND BRIDGE CORPORATION, Podgorica, Montenegro

## **Silver Sponsor**

SIKA SRBIJA, Šimanovci, Serbia

## **Bronze Sponsors**

ARDEX Baustoff GmbH, Loosdorf, Austria

BBR ADRIA, Zagreb, Croatia

CEMEX MONTENEGRO, Podgorica, Montenegro

INSTITUT ZA GRAĐEVINARSTVO, Podgorica, Montenegro

INSTITUTE FOR THE DEVELOPMENT OF WATER RESOURCES  
“JAROSLAV ČERNI”, Belgrade, Serbia

STRABAG, Podgorica, Montenegro

# GNP 2022 SPONSORS

## Friends of the Conference

ADING, Skopje, North Macedonia

CG RAD, Podgorica, Montenegro

DIASEN srl, Sassoferrato, Ancona, Italy

FONDACIJA PROFESOR ARSENIJE VUJOVIĆ, Podgorica, Montenegro

GeoGIS CONSULTANTS, Belgrade, Serbia

GEOPROJEKT, Podgorica, Montenegro

LOVČEN OSIGURANJE, Podgorica, Montenegro

MONTEPUT – PJ AUTOPUT BAR-BOLJARE, Podgorica, Montenegro

M SOLUTIONS, Podgorica, Montenegro

NATIONAL WATER ADMINISTRATION OF MONTENEGRO  
Podgorica, Montenegro

NESHVYL, Belgrade, Serbia

PRODUKT BG INŽENJERING, Belgrade, Serbia

VIGORIS ECOTECH, Podgorica, Montenegro

## Donors

AGENCY FOR ELECTRONIC COMMUNICATIONS AND POSTAL SERVICES  
Podgorica, Montenegro

CAPITAL CITY PODGORICA, Montenegro

INSTITUTE FOR STANDARDIZATION OF MONTENEGRO  
Podgorica, Montenegro

MINISTRY OF ECOLOGY, SPATIAL PLANNING AND URBANISM  
Podgorica, Montenegro

MUNICIPALITY OF KOLAŠIN, Montenegro

NIKCOM, Nikšić, Montenegro

# GNP 2022 Scientific Committee

## INTERNATIONAL SCIENTIFIC BOARD

**Professor Emeritus Charalampos Baniotopoulos**

Aristotle University of Thessaloniki, Thessaloniki, Greece  
University of Birmingham, Birmingham, United Kingdom

**Prof. Dr Miroslav Bešević**

University of Novi Sad, FCE Subotica, Subotica, Serbia

**Prof. Dr Paulo Barreto Cachim**

University of Aveiro, Aveiro, Portugal

**Prof. Dr Cristina Câmpian**

Technical University of Cluj-Napoca, Cluj-Napoca, Romania

**Prof. Dr Corneliu Cismasiu**

University NOVA, Lisbon, Portugal

**Prof. Dr Ildi Cismasiu**

University NOVA, Lisbon, Portugal

**Prof. Dr Anca Constantin**

Ovidius University of Constanta, Constanta, Romania

**Assoc. Prof. Dr Saša Čvoro**

University of Banja Luka, Banja Luka, Bosnia and Herzegovina

**Prof. Dr Szymon Dawczyński**

Silesian University of Technology, Gliwice, Poland

**Prof. Dr Luisa María Gil Martín**

University of Granada, Granada, Spain

**Prof. Dr Marcin Górski**

Silesian University of Technology, Gliwice, Poland

**Prof. Dr Ay Lie Han**

Diponegoro University, Semarang, Indonesia



**Assoc. Prof. Dr Tomáš Hanák**  
Brno University of Technology, Brno, Czech Republic

**Prof. Dr Wei Hao**  
Changsha University of Science and Technology, Changsha, China

**Prof. Dr Enrique Hernández Montes**  
University of Granada, Granada, Spain

**Dr Micha Horacek**  
BLT Wieselburg HBLFA Francisco Josephinum, Vienna, Austria

**Prof. Dr Adnan Ibrahimović**  
University of Tuzla, Tuzla, Bosnia and Herzegovina

**Assoc. Prof. Dr Nikša Jajac**  
University of Split, Split, Croatia

**Prof. Dr Miloš Knežević**  
University of Montenegro, Podgorica, Montenegro

**Assist. Prof. Dr Mitja Košir**  
University of Ljubljana, Ljubljana, Slovenia

**Prof. Dr Janusz Witalis Kozubal**  
Wrocław University of Technology, Wrocław, Poland

**Prof. Dr Vladan Kuzmanović**  
University of Belgrade, Belgrade, Serbia

**Prof. Dr Stjepan Lakušić**  
University of Zagreb, Zagreb, Croatia

**Prof. Dr Duško Lučić**  
University of Montenegro, Podgorica, Montenegro

**Assoc. Prof. Dr Maria Mavrova-Guirguinova**  
University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria

**Assoc. Prof. Dr Esad Mešić**  
University of Sarajevo, Sarajevo, Bosnia and Herzegovina

**Prof. Dr Nicola Nistico**  
Sapienza University of Rome, Rome, Italy

**Prof. Dr Hartmut Pasternak**  
Brandenburg University of Technology, Cottbus – Senftenberg, Germany

**Prof. Dr Maja Prskalo**  
University of Mostar, Mostar, Bosnia and Herzegovina

**Prof. Dr Vlastimir Radonjanin**  
University of Novi Sad, FTS, Novi Sad, Serbia

**Prof. Dr Marina Rakočević**  
University of Montenegro, Podgorica, Montenegro

**Assoc. Prof. Dr Aleksandar Ristovski**  
Faculty of Technical Sciences, Kosovska Mitrovica

**Prof. Dr Maria Fernanda da Silva Rodrigues**  
University of Aveiro, Aveiro, Portugal

**Assoc. Prof. Dr Mili Selimotić**  
University Džemal Bijedić, Mostar, Bosnia and Herzegovina

**Prof. Dr Božo Soldo**  
University North, Varaždin, Croatia

**Prof. Dr Zlatko Srbinoski**  
Ss. Cyril and Methodius University, FCE, Skopje, North Macedonia

**Assoc. Prof. Dr Milena Stavrić**  
Graz University of Technology, Graz, Austria

**Assoc. Prof. Dr Biljana Šćepanović**  
University of Montenegro, Podgorica, Montenegro

**Assoc. Prof. Dr Vlatko Šešov**  
Ss. Cyril and Methodius University, IZIIS, Skopje, North Macedonia

**Prof. Dr Andrej Šoltész**  
Slovak University of Technology, Bratislava, Slovak Republic

**Prof. Dr Ivana Štimac Grandić**  
University of Rijeka, Rijeka, Croatia

**Prof. Dr Slaviša Trajković**  
University of Niš, Niš, Serbia

**Assoc. Prof. Dr Damir Varevac**  
Josip Juraj Strossmayer University, Osijek, Croatia

**Prof. Dr Milan Veljković**  
Delft University of Technology, Delft, The Netherlands

**Prof. Dr Guoxin Wang**

Dalian University of Technology, Dalian, China

**Prof. Dr Vesna Žegarac Leskovar**

University of Maribor, Maribor, Slovenia

## **REVIEW BOARD**

**Assoc. Prof. Dr Srđa Aleksić**

University of Montenegro, Podgorica, Montenegro

**Prof. Dr Ivana Banjad Pečur**

University of Zagreb, Zagreb, Croatia

**Prof. Dr Meri Cvetkovska**

Ss. Cyril and Methodius University, FCE, Skopje, North Macedonia

**Assist. Prof. Dr Ivana Ćipranić**

University of Montenegro, Podgorica, Montenegro

**Prof. Dr Velimir Dutina**

Faculty of Technical Sciences, Kosovska Mitrovica

**Prof. Dr Nebojša Đuranović**

University of Montenegro, Podgorica, Montenegro

**Assist. Prof. Dr Radovan Đurović**

University of Montenegro, Podgorica, Montenegro

**Prof. Dr Nađa Folić**

University of Novi Sad, FTS, Novi Sad, Serbia

**Professor Emeritus Radomir Folić**

University of Novi Sad, FTS, Novi Sad, Serbia

**Prof. Dr Emina Hadžić**

University of Sarajevo, Sarajevo, Bosnia and Herzegovina

**Prof. Dr Nenad Ivanišević**

University of Belgrade, Belgrade, Serbia

**Assist. Prof. Dr Biljana Ivanović**  
University of Montenegro, Podgorica, Montenegro

**Prof. Dr Srđan Janković**  
University of Montenegro, Podgorica, Montenegro

**Assist. Prof. Dr Marija Jevrić**  
University of Montenegro, Podgorica, Montenegro

**Assist. Prof. Dr Tatjana Kočetov Mišulić**  
University of Novi Sad, FTS, Novi Sad, Serbia

**Prof. Dr Đorđe Lađinović**  
University of Novi Sad, FTS, Novi Sad, Serbia

**Prof. Dr Mirjana Malešev**  
University of Novi Sad, FTS, Novi Sad, Serbia

**Assoc. Prof. Dr Ljubo Marković**  
Faculty of Technical Sciences, Kosovska Mitrovica

**Prof. Dr Zlatko Marković**  
University of Belgrade, Belgrade, Serbia

**Assist. Prof. Dr Jelena Pejović**  
University of Montenegro, Podgorica, Montenegro

**Prof. Dr Radenko Pejović**  
University of Montenegro, Podgorica, Montenegro

**Prof. Dr Miroslav Premrov**  
University of Maribor, Maribor, Slovenia

**Assoc. Prof. Dr Milan Radulović**  
University of Montenegro, Podgorica, Montenegro

**Assist. Prof. Dr Milivoje Rogač**  
University of Montenegro, Podgorica, Montenegro

**Assist. Prof. Dr Snežana Rutešić**  
University of Montenegro, Podgorica, Montenegro

**Prof. Dr Todorka Samardžioska**  
Ss. Cyril and Methodius University, FCE, Skopje, North Macedonia

**Prof. Dr Goran Sekulić**

University of Montenegro, Podgorica, Montenegro

**Assoc. Prof. Dr Radmila Sindić Grebović**

University of Montenegro, Podgorica, Montenegro

**Prof. Dr Boško Stevanović**

University of Belgrade, Belgrade, Serbia

**Assoc. Prof. Dr Merima Šahinagić-Isović**

University Džemal Bijedić, Mostar, Bosnia and Herzegovina

**Prof. Dr Zvonko Tomanović**

University of Montenegro, Podgorica, Montenegro

**Prof. Dr Milan Trivunić**

University of Novi Sad, FTS, Novi Sad, Serbia

**Prof. Dr Mladen Ulićević**

University of Montenegro, Podgorica, Montenegro

**Prof. Dr Dušan Vuksanović**

University of Montenegro, Podgorica, Montenegro

**Assoc. Prof. Dr Zlatko Zafirovski**

Ss. Cyril and Methodius University, FCE, Skopje, North Macedonia

**Prof. Dr Radomir Zejak**

University of Montenegro, Podgorica, Montenegro

**Assist. Prof. Dr Slobodan Živaljević**

University of Montenegro, Podgorica, Montenegro

**Assoc. Prof. Dr Ljiljana Žugić**

University of Montenegro, Podgorica, Montenegro

# **GNP 2022 Organising Committee**

*University of Montenegro  
Faculty of Civil Engineering*

*NGO “Građevinarstvo – nauka i praksa – GNP”  
Podgorica, Montenegro*

*Prof. Marina Rakočević, Dr.-Ing.*

*Prof. Miloš Knežević, Dr.-Ing.*

*Assoc. Prof. Biljana Šćepanović, Dr.-Ing.*

*Assoc. Prof. Olga Mijušković, Dr.-Ing.*

*Assist. Prof. Ivana Čipranić, Dr.-Ing.*

*Assist. Prof. Marija Jevrić, Dr.-Ing.*

*Mladen Gogić, MSc*

*Mladen Muhadinović, MSc*

*Miodrag Bujišić, MSc*

*Petar Subotić, MSc*

*Ivana Drobnjak, MSc*

*Nina Nikolić, MSc*

*Milena Ostojić, MSc*

## THE FOREWORD

*Traditionally, for the eighth time now, the International Conference “Civil Engineering – Science and Practice”, GNP 2022 gathers us aiming at considering various topics and exchanging ideas of contemporary trends in civil engineering, once again in beautiful Kolašin.*

*The previous conference GNP 2020 had to be finished one day earlier than planned, due to the outbreak of COVID-19 pandemic. It has been followed by two-year period of slow investment activities, not only in the domain of civil engineering, and rapid ICT development. One of the aims of GNP 2022 is to contribute to the change of the current economic situation and, consequently, to the evolution of construction sector, through innovation, research, discussions and exchange of views.*

*GNP 2022 Proceedings collects 126 papers of 290 authors. Much higher number of conference participants, from 26 countries of Europe and beyond, give their precious contribution to GNP 2022, not only through writing, but also through other forms of active participation, such as paper reviewing and presentation, personal presence or online lecturing, significant support of sponsors and friends from Montenegro and abroad. We are grateful to all these colleagues and companies/institutions for enabling this GNP conference to be as it is.*

*Special thanks for all support and assistance in GNP 2022 realisation to the co-organiser – Engineers Chamber of Montenegro, Chamber of Civil Engineers.*

*We do hope discussions and presentations from GNP 2022 will be an additional incentive to advance the future of construction, in function of peace and progress of humanity.*

*Podgorica, March 2022*

*GNP 2022 ORGANISING COMMITTEE*







**8<sup>TH</sup> INTERNATIONAL CONFERENCE  
CIVIL ENGINEERING - SCIENCE AND PRACTICE**

**KOLAŠIN, 8-12 MARCH 2022**

---

**TABLE OF CONTENTS**

**INVITED LECTURES ..... 1**

*Paulo Cachim*

**SMART CARBON-CONCRETE SENSORS  
FOR TRANSPORT INFRASTRUCTURES ..... 3**

*Jelena Dobrić*

**STABILITY CRITERIA FOR STAINLESS STEEL  
EQUAL-LEG ANGLE COLUMNS ..... 15**

*Luisa María Gil-Martín, Luisa María Hdz-Gil, Stefano Miccoli, Enrique Hernández-Montes*

**ORIGIN OF THE CATENARY, THE TRUE FORM  
OF THE ARCH: TAQ-I KISRA ..... 39**

*Hartmut Pasternak*

**EXTRAORDINARY STEEL STRUCTURES IN GERMANY ..... 45**

*Svetislav Popović, Christian Stelzl*

**STATE OF THE ART IN THE DESIGN OF STEEL ROLLER-COASTERS ..... 55**

*Ivana Štimac Grandić*

**VIBRATION SERVICEABILITY OF FOOTBRIDGES: CURRENT STATE  
AND COMMENTARY ON CODES, NORMS AND GUIDELINES ..... 71**

**THEORETICAL AND EXPERIMENTAL RESEARCH  
IN CIVIL ENGINEERING ..... 93**

*Senka Bajić, Vladimir Vukobratović*

**EARTHQUAKE-INDUCED SNOW AVALANCHES:  
THE CRITICAL HEIGHT OF A SNOW LAYER ..... 95**

*Vasilije Bojović, Marina Rakočević*

**FREE VIBRATION ANALYSIS OF SYMMETRIC  
CROSS-PLY LAMINATED COMPOSITE PLATES ..... 101**

<i>Meri Cvetkovska, Koce Todorov, Maosen Cao, Vladimir Vitanov, Cvetanka Chifliganec, Milica Jovanoska, Riste Volcev, Nikola Postolov</i>	
<b>NUMERICAL ANALYSIS ON FIRE RESISTANCE OF RC FRAME STRUCTURES DAMAGED BY SEISMIC ACTION .....</b>	<b>111</b>
<i>Aleksandar Čeranić, Milica Bendić, Saša Kovačević, Nenad Marković</i>	
<b>INFLUENCE OF LONGITUDINAL STIFFENERS ON BEHAVIOR AND ULTIMATE RESISTANCE OF PLATE GIRDERS SUBJECTED TO PATCH LOADING .....</b>	<b>119</b>
<i>Marina Četković</i>	
<b>LAYERWISE FINITE ELEMENT FOR FREE VIBRATION OF GEOMETRICALLY IMPERFECT COMPOSITE PLATES .....</b>	<b>127</b>
<i>Ivana Drobnjak, Jelena Pejović</i>	
<b>SEISMIC ASSESSMENT OF AN EXISTING REINFORCED CONCRETE BUILDING .....</b>	<b>135</b>
<i>Ivan Duvnjak, Suzana Ereiz, Domagoj Damjanović, Marko Bartolac, Janko Koščak, Jurica Pajan</i>	
<b>CHALLENGES IN MODEL UPDATING OF CULTURAL HERITAGE STRUCTURES .....</b>	<b>143</b>
<i>Filip Đorđević, Svetlana M. Kostić</i>	
<b>PREDICTION OF ULTIMATE COMPRESSIVE STRENGTH OF CCFT COLUMNS USING MACHINE LEARNING ALGORITHMS .....</b>	<b>151</b>
<i>Mirjana Đukić, Zlatko Marković, Duško Lučić</i>	
<b>PRE-EXPERIMENTAL ANALYSIS OF ASYMMETRIC COMPOSITE SLIM FLOOR BEAM WITH WEB OPENINGS .....</b>	<b>159</b>
<i>Eduard Fot, Dalibor Gelo, Šime Serdarević, Daniel Martinović</i>	
<b>DYNAMIC ANALYSIS OF A MULTI-STOREY STRUCTURE USING MULTIPLE DYNAMIC METHODS .....</b>	<b>167</b>
<i>Milena Janković, Duško Lučić</i>	
<b>CODE FOR THE DESIGN AND OPTIMIZATION OF K GAP JOINTS COMPOSED OF CIRCULAR HOLLOW SECTIONS .....</b>	<b>175</b>
<i>Đorđe Jovanović, Tanja Nožica</i>	
<b>NUMERICAL ANALYSIS OF STEEL STAIRS VIBRATIONS .....</b>	<b>183</b>
<i>Marino Jurišić, Alen Harapin</i>	
<b>EXPERIMENTAL STRAIN MEASUREMENTS OF A PRESTRESSED BALANCED CANTILEVER BRIDGE .....</b>	<b>191</b>
<i>Šemso Kalač, Naja Zejnelagić, Đorđe Đuričić, Duško Lučić</i>	
<b>PROPOSAL OF ANALYTICAL EXPRESSION FOR DETERMINATION OF LOAD CAPACITY FOR ALUMINIUM SQUARE HOLLOW SECTION (SHS) K JOINTS UNDER CHORD TENSION .....</b>	<b>199</b>
<i>Kopitović-Vuković, Radomir Zejak, Marija Jevrić, Nikola Baša</i>	
<b>DEFLECTION CALCULATION OF RC T-BEAMS EXTERNALLY STRENGTHENED WITH CARBON MATERIAL .....</b>	<b>207</b>

<i>Stojan Kravanja, Tomaž Žula, Primož Jelušič</i> <b>OPTIMIZATION OF STEEL AND TIMBER HALLS .....</b>	<b>217</b>
<i>Dejan Matic, Jelena Dobrić, Milan Spremić</i> <b>PREDICTED ULTIMATE RESISTANCES OF COMPRESSED COLD-FORMED CHANNEL SECTIONS ACCORDING TO EFFECTIVE WIDTH METHOD AND DIRECT STRENGTH METHOD .....</b>	<b>225</b>
<i>Aleksandar Milajić, Dejan Beljaković, Zorica Milovanović Jeknić, Lejla Vujičić, Irena Parović</i> <b>COMPARATIVE ANALYSIS OF HYBRID MULTI-OBJECTIVE ALGORITHMS FOR STRUCTURAL OPTIMIZATION .....</b>	<b>233</b>
<i>Milica Mirković Marjanović, Snežana Ilić, Aleksandar Kijanović, Goran Todorović, Radovan Gospavić</i> <b>EXPERIMENTAL ANALYSIS OF FIRE RESISTANCE OF CLAY HOLLOW-BRICK MASONRY NON-LOAD BEARING WALL .....</b>	<b>241</b>
<i>Zoran Mišković, Marina Latinović Krndija, Marko Popović, Siniša Savatović</i> <b>MODAL ANALYSIS OF THE SUSPENSION FOOTBRIDGE OVER RIVER VRBAS IN BANJA LUKA .....</b>	<b>249</b>
<i>Zoran Mišković, Vesna Lazarević, Milorad Ivetić, Miloš Hranisavljević, Ljiljana Mišković</i> <b>STRAIN MEASUREMENTS DURING STATIC PILE TESTING: A CASE STUDY OF TWO PILES WITH DIFERENT DIAMETER AND LENGTH .....</b>	<b>257</b>
<i>Ivan Nackov, Jelena Dobrić</i> <b>STRUCTURAL PERFORMANCE OF HIGH STRENGTH STEEL I AND H SECTIONS .....</b>	<b>265</b>
<i>Nina Nikolić, Biljana Šćepanović</i> <b>ANALYSIS OF PRESSED BRACE AND K-JOINT OF WELDED ALUMINIUM LATTICE STRUCTURE MADE OF CHS PROFILES .....</b>	<b>273</b>
<i>Bojan Raspopović, Slobodan Živaljević</i> <b>EXPERIMENTAL TESTING OF THE ENERGY ABSORPTION CAPACITY OF SHOTCRETE .....</b>	<b>281</b>
<i>Milivoje Rogač, Srđa Aleksić, Duško Lučić</i> <b>TESTING OF THIN-WALLED I-GIRDER SUBJECTED TO PATCH LOADING ...</b>	<b>289</b>
<i>Radmila Sindić Grebović</i> <b>MODELLING OF HIGH-STRENGTH CONCRETE IN THE SHEAR TRANSFER ZONE .....</b>	<b>297</b>
<i>Anka Starčev-Čurčin, Andrija Rašeta, Miloš Šešljija, Igor Džolev, Dragan Manojlović</i> <b>EXPERIMENTAL TESTING AND NUMERICAL ANALYSIS OF REINFORCED CONCRETE WALL MEMBERS .....</b>	<b>305</b>
<i>Petar Subotić, Biljana Šćepanović</i> <b>IMPROVED <math>M_{cr}</math>-L CURVES FOR HOT ROLLED IPE SECTIONS .....</b>	<b>315</b>
<i>Andrej Štrukelj</i> <b>MEASUREMENTS OF VEHICLE RESPONSE TO WIND GUSTS DURING TESTING THE EFFECTIVENESS OF WINDBREAKS .....</b>	<b>323</b>

<i>Vladimir Živaljević, Milan Blagojević, Đorđe Jovanović, Dušan Kovačević</i> <b>GEOMETRY CONTROL OF THE COLD-FORMED STEEL MEMBERS USING THE OPTICAL 3D MEASURING SYSTEM .....</b>	<b>333</b>
<i>Tomaž Žula, Stojan Kravanja, Primož Jelušič</i> <b>SUSTAINABILITY PROFIT GENERATED BY THE OPTIMIZATION OF SIMPLY SUPPORTED BEAMS .....</b>	<b>341</b>

## **DESIGN AND BUILDING OF STRUCTURES ..... 347**

<i>Goran Milutinović</i> <b>TIED ARCH BRIDGE AT 2ND AVENUE OVER I-94, DETROIT, U.S.A.: EXPERIENCES DURING VALUE ENGINEERING PROPOSAL AND CONSTRUCTION ENGINEERING .....</b>	<b>349</b>
<i>Radenko Pejović, Nikola Luković, Bojan Đonović, Jelena Pejović, Mladen Muhadinović</i> <b>STRUCTURAL AND ARCHITECTURAL DESIGN OF SMOKOVAC TOLL COLLECTION RAMP ON THE SECTION OF THE SMOKOVAC-MATEŠEVO HIGHWAY .....</b>	<b>357</b>
<i>Radenko Pejović, Nikola Luković, Jelena Pejović, Bojan Đonović, Nina Serdar, Mladen Muhadinović</i> <b>STRUCTURAL AND ARCHITECTURAL DESIGN OF MAINTENANCE BASE ON PELEV BRIJEG FOR SECTION OF THE SMOKOVAC-MATEŠEVO HIGHWAY .....</b>	<b>365</b>
<i>Milan Spremić, Nemanja Dinčić, Isidora Jakovljević, Nina Gluhović, Jelena Dobrić</i> <b>FIRE LOAD FOR PERFORMANCE FIRE DESIGN OF CAR PARK STEEL STRUCTURE .....</b>	<b>373</b>

## **ASEISMIC PLANNING, DESIGN AND BUILDING ..... 381**

<i>Dejan Dragojević, Željko Žugčić, Dušan Berisavljević</i> <b>SITE SPECIFIC GROUND MOTION EARTHQUAKE RESPONSE STUDY – CASE STUDY AT THE SITE OF CANADIAN EMBASSY RESIDENCE IN BELGRADE .....</b>	<b>383</b>
<i>Daniel Martinović, Šime Serdarević, Dalibor Gelo, Eduard Fot,</i> <b>CALCULATION OF SEISMIC RESISTANCE OF AN EXISTING BUILDING .....</b>	<b>393</b>
<i>Ivan Mrdak</i> <b>NONLINEAR STATIC ANALYSIS OF FRAME STRUCTURE DESIGNED IN ACCORDANCE WITH EUROCODE 8 .....</b>	<b>401</b>
<i>Aleksandra Radujković, Đorđe Lađinović</i> <b>SEISMIC RESPONSE OF RC FRAMES FOR TWO LIMIT STATES ACCORDING TO EN 1998-3 .....</b>	<b>409</b>

*Nina Serdar, Jelena Pejović*

**CHALLENGES IN DEVELOPING NATIONAL SEISMIC RISK ASSESSMENT .... 415**

*Vladimir Vukobratović, Dragan Manojlović, Ivan Lukić*

**SEISMIC RESPONSE OF AN EXISTING MASONRY MONASTERY TOWER ..... 423**

## **SPECIAL ISSUES OF DESIGN AND CONSTRUCTION ..... 431**

*Nikola Čadenović*

**CONSTRUCTION METHOD FOR TUNNEL UNDER THE BAY OF KOTOR ..... 433**

*Radomir Folić, Nenad Stojković, Zoran Brujić*

**SERVICE LIFE AND DURABILITY OF CONCRETE  
STRUCTURE - SUSTAINABLE CONSTRUCTION ..... 445**

*Dorđe Jovanović, Drago Žarković, Ivan Pijanić*

**NON-LINEAR ANALYSIS AS TOOL FOR DAMAGE EXPLANATION  
OF SILO GALERY STRUCTURE ..... 455**

*Cveta Lazić, Suzana Draganić, Olivera Bukvić, Mirjana Laban, Meri Cvetkovska*

**FIRE RISK ASSESSMENT IN RESIDENTIAL UNITS ..... 463**

*Miroslav Premrov, Vesna Žegarac Leskovar*

**STUDY ON MULTI-FUNCTIONAL ANALYSIS  
OF HIGH-RISE TIMBER BUILDINGS ..... 471**

*Bratislav Stipanić*

**ERECTION EXAMPLES OF STEEL BRIDGES OVER SAVA RIVER ..... 481**

## **BUILDING MATERIALS ..... 491**

*Katarina Didulica, Ana Baričević, Ivana Banjad Pečur*

**A REVIEW OF EARLY AGE SHRINKAGE DEFORMATIONS  
IN CEMENTITIOUS COMPOSITES ..... 493**

*Ivan Gabrijel, Ivana Banjad Pečur*

**ASSESSMENT OF CONCRETE COMPRESSIVE STRENGTH IN  
STRUCTURES - COMPARISON OF PAST AND CURRENT PRACTICES ..... 501**

*Ksenija Janković, Marko Stojanović, Dragan Bojović, Anja Terzić, Srboľjub Stanković*

**INFLUENCE OF WATER/CEMENT RATIO ON THE PROPERTIES  
OF FRESH SCC WITH FLY ASH ADDITION ..... 509**

*Tatjana Kočetov Mišulić, Aleksandra Radujković*

**DIFFERENCIES IN STATISTICAL EVALUATION  
OF TIMBER BENDING STRENGTH ACCORDING EN 8 AND EN 8 ..... 517**

<i>Slobodan Šupić, Vesna Bulatović, Mirjana Malešev, Vlastimir Radonjanin, Vladan Pantić</i> <b>FROM WASTE TO RESOURCE - PART 1: CHARACTERIZATION OF FLY ASH, SLAG AND WHEAT STRAW ASH .....</b>	<b>525</b>
<i>Slobodan Šupić, Vesna Bulatović, Mirjana Malešev, Vlastimir Radonjanin, Vladan Pantić</i> <b>FROM WASTE TO RESOURCE - PART 2: MASONRY MORTAR INCORPORATING FLY ASH, SLAG AND WHEAT STRAW ASH .....</b>	<b>533</b>
<i>Radimir Zejak, Senka Zečević, Katarina Mirković</i> <b>THE POSSIBILITY OF USING FLY ASH FROM THE LANDFILL MALJEVAC AND THE TPP PLJEVLJA IN CONCRETE PRODUCTION .....</b>	<b>543</b>

## **MAINTENANCE AND REPAIR OF STRUCTURES**

### **MONITORING OF STRUCTURES DURING CONSTRUCTION AND EXPLOITATION ..... 551**

<i>Miroslav Bešević, Neđo Đurić, Martina Vojnić Purčar, Ljiljana Kozarić, Smilja Bursac</i> <b>LOAD BEARING STRUCTURE OF THE EXCHANGE STATION OF BLOCK A TENT A - OBRENOVAC .....</b>	<b>553</b>
--	------------

<i>Miloš Knežević, Ivana Tešović, Radenko Pejović, Duško Lučić, Kemal Abdić, Miloš Vučinić, Teodora Bulatović, Kostantin Dragović, Jelena Perović, Ivan Popović, Anđela Jašović</i> <b>COMPLEXITY OF REHABILITATION WORKS ON THE CONCRETE BRIDGES ON THE RAILWAY LINE "VRBNICA-BAR" ....</b>	<b>565</b>
---	------------

<i>Liljana B. Mijalkova, Elena Delova, Živko Božinovski</i> <b>ANALITICAL APROACH FOR STRENGTHENING OF HISTORIC BUILDING "ARMY CLUB" IN BITOLA DAMAGED IN THE 1994 EARTHQUAKE .....</b>	<b>573</b>
--	------------

<i>Dragan Žarković, Stefanela Žarković</i> <b>QUALITY OF ALL PHASES OF THE LIFE CYCLE OF ENGINEERING FACILITIES - SAFETY CONDITION AND BEST PROTECTION AGAINST DAMAGE. CASE EXAMPLE: ANTENNA PILLAR DEMOLITION .....</b>	<b>581</b>
---	------------

### **BUILDING REGULATIONS AND CODES ..... 589**

<i>Milica Mirković Marjanović, Snežana Ilić, Aleksandar Kijanović, Goran Todorović, Radovan Gospavić</i> <b>OVERVIEW OF THE NEW RULEBOOK ON TESTING FIRE RESISTANCE, EXTERNAL FIRE PERFORMANCES AND REACTION TO FIRE IN THE REPUBLIC OF SERBIA .....</b>	<b>591</b>
---	------------

<i>Mladen Muhadinović, Petar Subotić, Duško Lučić</i> <b>OVERVIEW OF NATIONALLY DETERMINED PARAMETERS IN EN 1993-1-8 ..</b>	<b>599</b>
--	------------

*Petar Subotić, Mladen Muhadinović, Duško Lučić*

**OVERVIEW OF NATIONALLY DETERMINED PARAMETERS IN EN 1993-1-1 .. 607**

## **PLANNING, DESIGN AND CONSTRUCTION OF ROADS AND RAILWAYS ..... 617**

*Laura Brigita Parežnik, Marko Renčelj*

**COMPARISON OF DESIGN ELEMENTS REGARDING GRADE-SEPARATED  
INTERCHANGES AND JUNCTIONS BETWEEN DIFFERENT COUNTRIES ..... 619**

*Riste Ristov, Ivona Nedevska, Zlatko Zafirovski, Vasko Gacevski, Marijana Lazarevska*

**PROCESS OF DESIGNING AN ACCESS ROAD  
AND A WINDMILL PLATEAU IN BOGDANCI ..... 627**

*Riste Ristov, Ivona Nedevska, Zlatko Zafirovski, Slobodan Ognjenovic, Vasko Gacevski*

**MEASURES TO IMPROVE SAFETY ON EXISTING MAIN STREET 101 ..... 635**

## **SPATIAL, ARCHITECTURAL AND URBAN PLANNING AND DESIGN HERITAGE PROTECTION ..... 645**

*Nada Kurtović Folić, Radomir Folić*

**A CONTRIBUTION TO PREDICTING THE FUTURE OF CULTURAL HERITAGE .. 647**

*Ljubo Marković, Julija Aleksić, Rada Radulović, Mirjana Miletić*

**ECONOMIC BENEFITS FROM IMPROVING HOUSING  
CONTAINER CLADDING IN THE REPUBLIC OF SERBIA ..... 657**

*Nevena Mašanović, Marija Jevrić*

**MONTENEGRIN RURAL SETTLEMENTS – PATTERNS, ATTRIBUTES  
AND ISSUES, ACCORDING TO THE REGIONAL AFFILIATION ..... 665**

*Marija Mihajlović, Marko Mihajlović, Ljiljana Stošić Mihajlović*

**CONCEPT OF BIOCLIMATIC DESIGN AND PLANNING  
IN ARCHITECTURE AND BUILDINGS ..... 673**

*Jaka Potočnik, Mitja Košir*

**PREDICTING THE MELANOPIE POTENTIAL OF INDOOR  
COLOURED SURFACES USING ARTIFICIAL NEURAL NETWORKS ..... 681**

**ENVIRONMENTAL PROTECTION ..... 689**

*Marko Čeček, Ivana Čipranic, Merima Šahinagić-Isović, Radmila Marković, Zoran Stevanović*  
**THE POSSIBILITIES OF USING RED MUD IN BUILDING MATERIALS ..... 691**

*Gregor Kravanja, Andrej Ivanič, Samo Lubej*  
**TOWARDS GREEN CEMENT PRODUCTION ..... 699**

*Ivona Krulanović, Ivana Čipranić, Marija Jevrić, Milena Ostojčić*  
**POSSIBILITIES OF PREDICTIONS OF MUNICIPAL SOLID WASTE  
AMOUNT IN MONTENEGRO USING NEURAL NETWORKS ..... 705**

**ENERGY EFFICIENCY, ENERGY-EFFICIENT  
DESIGN AND BUILDING ..... 713**

*David Božiček, Mateja Dovjak*  
**IMPACT OF THERMAL INERTIA AND ROOM ORIENTATION ON  
ENERGY DEMAND AND THERMAL COMFORT IN AN OFFICE BUILDING ..... 715**

*Ivana Burić, Marija Nišavić*  
**PRINCIPLES OF ENERGY EFFICIENCY IN THE PROCESS  
OF DESIGNING RESIDENTIAL SETTLEMENT SADINE ..... 723**

*Liljana Dimevska, Meri Cvetkovska, Ana Trombeva Gavriloska, Mirjana Laban*  
**BUILDING ENERGY SIMULATION ANALYSIS BASED ON IN-SITU  
MEASUREMENTS BEFORE AND AFTER INSULATION APPLICATION ..... 731**

*Dragan Kostić, Veliborka Bogdanović, Miomir Vasov, Vuk Milošević, Marko Ilić*  
**METHODOLOGICAL APPROACH TO MANAGEMENT  
OF AMBIENT PARAMETERS IN ORDER TO PREVENT  
CONDENSATION ON STRUCTURAL TEXTILE MEMBRANES ..... 739**

*Veronica Martins Gnecco, Luka Pajek*  
**ANALYSIS OF FIXED SHADING DEVICES  
IN BRAZILIAN ELEMENTARY SCHOOLS  
REGARDING COOLING ENERGY DEMAND AND DAYLIGHTING ..... 747**

*Marija Mihajlović, Marko Mihajlović, Ljiljana Stošić Mihajlović*  
**SIGNIFICANCE AND ROLE OF ARCHITECTURE  
IN ENERGY EFFICIENT BUILDINGS ..... 755**

*Luka Pajek, Mitja Košir*  
**IMPLICATIONS OF PROJECTED RCP4.5 AND RCP8.5 CLIMATE CHANGE  
SCENARIOS FOR THE BIOCLIMATIC POTENTIAL OF PODGORICA ..... 763**

*Maja Prskalo, Tatjana Džeba, Amira Galić*  
**SUSTAINABILITY OF WATER SUPPLY SYSTEMS USING  
INTERNAL AND EXTERNAL RENEWABLE ENERGY SOURCES ..... 771**



**HYDROTECHNICS ..... 779**

*Ivana Čipranić, Marija Jevrić, Milena Ostojić, Goran Sekulić, Snežana Rutešić*  
**BURST FREQUENCY IN WATER DISTRIBUTION SYSTEM ..... 781**

*Matej Čehovin, Andreja Žgajnar Gotvajn*  
**HYBRID HYDRODYNAMIC CAVITATION AND ADVANCED OXIDATION  
 FOR REMOVAL OF NATURAL ORGANIC MATTER FROM  
 DRINKING WATER – SELECTED ASPECTS ..... 789**

*Goran Jeftenić, Ljubomir Budinski, Slobodan Kolaković, Danilo Stipić, Marijana Milić*  
**MATHEMATICAL MODELLING OF GROUNDWATER  
 LEVEL LOWERING USING GMS ..... 797**

*Milena Ostojić, Ivana Čipranić, Goran Sekulić*  
**CURRENT STATE OF NATIONAL FLOOD RISK ASSESSMENT  
 IN MONTENEGRO ..... 807**

*Siniša Višnjić, Krsto Minić, Saveta Đuričić*  
**THE SEWAGE SYSTEM IN PLJEVLJA - OPERATION CHALLENGES ..... 815**

*Siniša Višnjić, Krsto Minić, Saveta Đuričić*  
**ANALYSIS OF POSSIBILITIES OF MICRO HYDROPOWER PLANT  
 BUIL-UP ON THE DAPSIĆE WATER SUPPLY SYSTEM ..... 823**

**GEOLOGY, HYDROGEOLOGY AND GEOTECHNICS  
 IN CIVIL ENGINEERING ..... 831**

*Neđo Đurić, Miroslav Bešević, Smilja Bursać, Dijana Đurić*  
**CHARACTERISTICS OF LAPORY ROCKS AT THE SILOS LOCATION  
 WITHIN THE “MOLARIS” MILL COMPLEX, IN KOZLUK  
 NEAR ZVORNIK IN THE REPUBLIC OF SRPSKA ..... 833**

*Primož Jelušič, Stojan Kravanja, Tomaž Žula*  
**NUMERICAL MODELLING AND DESIGN  
 OF GEOSYNTHETIC REINFORCED SOIL BRIDGE ABUTMENT ..... 841**

*Borut Macuh, Sašo Kos*  
**RETAINING STRUCTURE PK-18 AS A PART OF RECONSTRUCTION  
 OF THE G2-108 HRASTNIK - ZIDANI MOST ROAD ..... 849**

*Snežana Maraš-Dragojević*  
**EUROCODE 7 AND DESIGN OF DEEP EXCAVATIONS  
 AND TUNNELS USING FINITE ELEMENT METHOD ..... 857**

*Borko Miladinović, Slobodan Živaljević, Zvonko Tomanović*  
**ESTIMATION OF THE STATIC VERTICAL SUBGRADE REACTION MODULUS .. 865**

*Borko Miladinović, Slobodan Živaljević, Zvonko Tomanović*  
**LATERALLY LOADED PILES IN WINKLER'S ELASTIC MEDIA ..... 873**

*Maja Prskalo, Ana Majstorović*

**ANALYSIS AND METHODS OF APPLICATION  
OF DIFFERENT EMBEDDED WALLS IN URBAN ENVIRONMENTS ..... 881**

**SURVEYING/GEODESY IN CIVIL ENGINEERING ..... 889**

*Tatjana Budimirov, Vladimir Bulatović, Marko Marković, Mehmed Batilović, Zoran Sušić*

**PRECISE POINT POSITIONING – PPP METHOD ..... 891**

*Tanja Đukanović, Sanja Tucikešić, Radovan Đurović*

**COMPARATIVE ANALYSIS COORDINATE USING METHODS  
OF GPS-RTK AND TOTAL STATION THE OF AN AREA LANDSLIDES ..... 899**

*Sanja Grekulović, Nikola Paunković, Dušan Petković,*

*Miljana Todorović Drakul, Slavica Ilijević*

**FIELD PROCEDURE FOR ESTIMATION OF ANTENNA  
PHASE CENTER VARIATION WITH EXPANDED  
MEASUREMENT UNCERTAINTY CALCULATION ..... 907**

*Jovana Maksimović, Mehmed Batilović, Zoran Sušić, Radovan Đurović, Marko Marković,*

*Vladimir Bulatović, Gojko Nikolić*

**PROJECT OF MICRO-NETWORK AND GEODETIC  
SETTING-OUT OF THE PRESLO BRIDGE ..... 915**

*Branko Milovanović, Slavko Vasiljević, Radovan Đurović, Jovan Popović, Petko Vranić*

**WIND TURBINE COLUMN GEOMETRY CONTROL ..... 923**

*Bilbil Nurçe, Eduart Blloshmi, Bledar Sina*

**CADASTRAL MAPPING IN ALBANIA ..... 931**

*Bilbil Nurçe, Bledar Sina, Eduart Blloshmi*

**TRANSFORMATION OF ELLIPSOIDAL HEIGHTS INTO ORTHOMETRIC  
THROUGH A LINEAR INTERPOLATION POLYNOMIAL ..... 939**

*Gligorije Perović*

**OPTIMIZATION OF GPS MEASUREMENT ACCURACY  
IN GEODETIC CONTROL NETWORKS ..... 947**

*Vladimir Petrović, Bogdan Bojović, Tatjana Đurić, Mirko Borisov, Zoran Ilić, Nenad Rakičević*

**GIS / 3D SOLUTIONS IN THE FUNCTION  
OF MANAGEMENT IMPROVEMENT IN AGRICULTURE ..... 959**

*Hakile Resulbegović, Biljana Stamatović*

**SPATIAL STATISTICS AND APPLICATION  
OF THE GLOBAL POSITIONING SYSTEM IN FIELD SURVEYS ..... 969**

*Milan Trifković, Miroslav Kuburić, Žarko Nestorović*

**THE INFLUENCE OF CHANGING POINTS' POSITION  
DURING MEASUREMENTS ON ADJUSTED COORDINATES  
IN SPECIAL GEODETIC NETWORKS ..... 975**

**MANAGEMENT IN CIVIL ENGINEERING ..... 983***Željka Beljkaš, Mladen Gogić, Nina Serdar***AN OVERVIEW OF THE STUDY ON TECHNICAL-TECHNOLOGICAL  
AND ORGANIZATIONAL ELEMENTS FOR THE CONSTRUCTION  
OF A BRIDGE ŠAMIČKI POTOK ON BUDVA BYPASS ..... 985***Željka Beljkaš, Mioš Knežević, Marko Knežević, Nadežda Lučić***CONSTRUCTION OF THE CONCRETE STRUCTURES –  
– LEGAL AND TECHNICAL REQUIREMENTS ..... 995***Zdravko Maksimović, Mirjana Laban, Sandra Nedeljković***FROM REACTION TO PREVENTION – SYSTEM OF CIVIL PROTECTION  
IN THE CITY OF KRALJEVO ..... 1005***Srđan Topalović, Lana Vukmirović-Mišić***DIFFERENCE BETWEEN ROLES OF THE ENGINEER AS PER FIDIC CONDITIONS  
OF CONTRACTS AND ENGINEERING SUPERVISION IN ACCORDANCE WITH  
LAW ON SPATIAL PLANNING AND CONSTRUCTION OF MONTENEGRO .... 1013***Dragan Žarković, Stefanela Žarković***RESEARCH OF THE IMPORTANCE OF LEGAL AND ECONOMIC ENVIRONMENT  
ON THE QUALITY OF CORPORATE GOVERNANCE, IN THE REALIZATION  
OF INVESTMENT ENTERPRISES IN CONSTRUCTION ..... 1023****INFORMATICS AND MULTIMEDIA TECHNOLOGY IN CIVIL  
ENGINEERING ..... 1031***Dorđe Donović, Jelena Pejović, Nina Serdar***TOWARDS MONTENEGRO SEISMIC RISK ASSESSMENT  
INFORMATION SYSTEM ..... 1033***Sofija Kekez***CHALLENGES OF PREDICTING ELECTRICAL BEHAVIOR  
OF SELF-SENSING CONCRETE ..... 1041***Ljubo Marković, Ljiljana Milić Marković, Nikola Gvozdović***APPLICATION OF BIM IN THE PROCESS OF MANAGEMENT  
OF CONSTRUCTION PROJECTS ..... 1049***Milan Marojević***BIM – FOUNDATION OF DIGITAL TRANSFORMATION  
IN CONSTRUCTION INDUSTRY ..... 1057***Dušanka Plazina-Pevač, Milan Trivunić, Igor Peško, Vladimir Mučenski, Željko Jakšić***DEFICIENCIES OF CLASSIC DESIGN IN RELATION TO BIM DESIGN:  
EXAMPLE OF MORGAVEL PHOTOVOLTAIC POWER PLANT ..... 1065**

*Mirjana Terzić, Igor Peško, Vladimir Mučenski, Milena Senjak Pejić, Dragana Stanojević*  
**MODELLING COMPLEX PREFABRICATED STAIRCASE USING BIM TOOLS .. 1073**

*Jelena Vilotijević, Dušan Rožič, Milan Kuhta*  
**ALLPLAN BRIDGE SOFTWARE FOR GEOMETRICAL  
AND ANALYTICAL MODELING OF KOZARICA BRIDGE ..... 1081**

**EDUCATION IN CIVIL ENGINEERING ..... 1089**

*Cristina Campian, Camelia Negrutiu, Maria Pop*  
**EUROPEAN UNIVERSITY OF TECHNOLOGY – A NEW APPROACH  
IN TEACHING THE TECHNOLOGY IN EUROPE ..... 1091**

*Aleksandar Milajić, Dejan Beljaković, Zorica Milovanović Jeknić,  
Lejla Vujičić, Kaltom Benansera*  
**DEVELOPING STUDENTS' EVALUATION SKILLS  
IN REINFORCED CONCRETE STRUCTURES DESIGN ..... 1097**

*Biljana Šćepanović, Branka Živković*  
**ENGLISH LANGUAGE IN CIVIL ENGINEERING ..... 1105**

*Jovana Topalić Marković, Dijana Đurić, Nenad Ivanišević, Vladimir Mučenski, Igor Peško*  
**SIGNIFICANCE OF COURSES ON CONSTRUCTION LEGAL REGULATIONS  
IN THE CURRICULUMS OF FACULTIES OF CIVIL ENGINEERING ..... 1111**

**GNP 2022 AUTHORS ..... 1121**

**PROFESSOR ARSENIJE VUJOVIĆ FOUNDATION ..... 1153**

**CO-ORGANISER ..... 1157**

**SPONSORS ..... 1165**



**THE 8<sup>th</sup> INTERNATIONAL CONFERENCE  
"CIVIL ENGINEERING – SCIENCE AND PRACTICE"**

**GNP 2022 – Kolašin, Montenegro, 8-12 March 2022**

---

*Riste Ristov<sup>1</sup>, Ivona Nedevska<sup>2</sup>, Zlatko Zafirovski<sup>3</sup>, Vasko Gacevski<sup>4</sup>, Marijana Lazarevska<sup>5</sup>*

**PROCESS OF DESIGNING AN ACCESS ROAD AND A WINDMILL  
PLATEAU IN BOGDANCI**

***Abstract***

Many countries invest heavily in wind energy to tackle climate change and secure energy supplies. It is a clean source and becomes more cost-effective with technological advancement and increased capacity per unit installed.

Wind energy as a power source is an attractive alternative to fossil fuels. However, wind farms are typically constructed in undeveloped rural areas with challenging topography. In addition, the lack of a road network leading to the site and within the site itself poses significant challenges to the planning of wind farm construction. Therefore, selecting the most appropriate access road route is essential in the overall planning of wind farm construction.

This paper presents a comprehensive view of the design process and will focus on selecting access road routes to optimize the general wind farm construction. An integrated framework for wind farm design is presented, and the problem of optimal access road selection is highlighted. Finally, a numeric example is shown, including conclusions, limitations, and suggestions for future research.

***Keywords***

Access road, windmill, construction process, basic design, road network, road design.

---

<sup>1</sup> Riste Ristov, MSc, Teaching Assistant, [ristov@gf.ukim.edu.mk](mailto:ristov@gf.ukim.edu.mk)

<sup>2</sup> Ivona Nedevska, MSc, Teaching Assistant, [nedevska@gf.ukim.edu.mk](mailto:nedevska@gf.ukim.edu.mk)

<sup>3</sup> Zlatko Zafirovski, PhD, Associate Professor, [zafirovski@gf.ukim.edu.mk](mailto:zafirovski@gf.ukim.edu.mk)

<sup>4</sup> Vasko Gacevski, MSc, Teaching Assistant, [gacevski@gf.ukim.edu.mk](mailto:gacevski@gf.ukim.edu.mk)

<sup>5</sup> Marijana Lazarevska, PhD, Associate Professor, [marijana@gf.ukim.edu.mk](mailto:marijana@gf.ukim.edu.mk)

## 1. INTRODUCTION

Wind energy is one of the most relevant renewable energy systems. However, planning and constructing a wind farm becomes increasingly complicated. Regulation on distance, acoustic emission, shadow flicker, and bird strike prevention increases the degree of complexity. This results in fewer and less available locations.

The optimization of wind farms deals with many different challenges and restrictions. One example is access to a wind turbine or wind farm. Access roads are determined to be 3 % of the initial investment costs [1, 2]. Those roads must be passable at all times. In some cases, the access roads need to be constructed, especially for the wind farm, resulting in an increased investment cost.

An optimal layout of a wind farm's access roads consists of straight roads connecting the turbines directly and an existing road network. Nonetheless, the curvature of the roads and construction sites of the wind turbine must be considered to use the access roads fully. This has been understood and researched.

This paper aims to investigate the influence of access roads on a wind farm layout optimization with minimal Levelled Cost of Energy (LCOE). Placing the wind turbine closer to existing roads or closer to each other leads to reduced road investment cost while the Annual Energy Product (AEP) is reduced. Consequently, the access roads are introduced as an additional aspect during the optimization. Furthermore, the access roads are designed such that it is possible to construct the wind turbines simultaneously while no construction site obstructs another one. This paper is presented by developing a new road network while optimizing the layout.

## 2. GENERAL PROJECTS DETAILS

The research subject is the technical documentation for an access road for heavy goods vehicles that will enable connection from the existing local road Stojakovo - Bogdanci with the locations where the windmills will be installed.

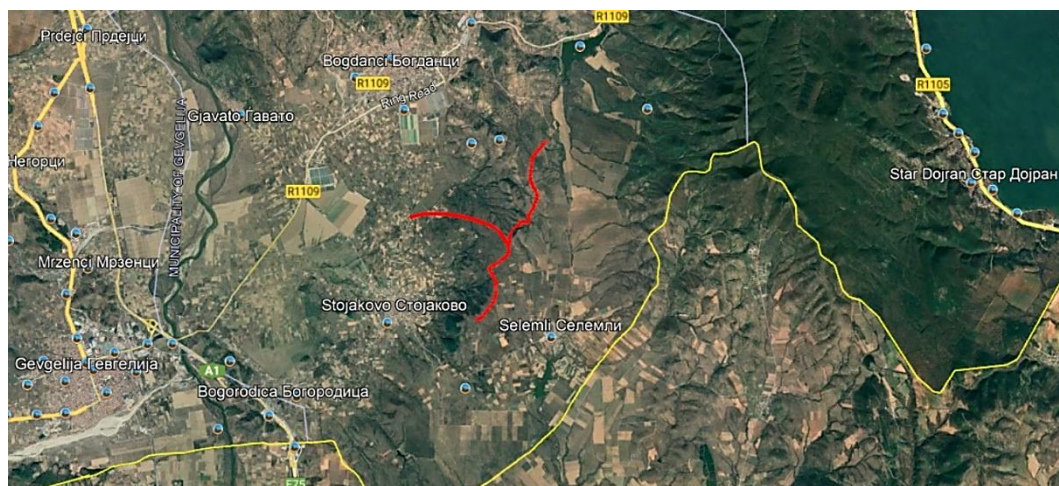


Figure 1. Location of the access road

During the preparation of the basic design, topographic maps in scale  $R = 1:25\ 000$  and a base obtained by the tachymetric recording of the existing condition were used as design bases. The recorded geodetic base is made on a scale of  $R = 1:1\ 000$ , on which the actual field condition is defined. During the field shooting, a wider band is covered concerning the foreseen contents, which will enable possible changes during the design.

Objects of this character as objects with application in various and specific conditions do not have strict regulations regarding the border elements. Instead, the geometric characteristics of the route are defined according to the needs and requirements determined by the Investor. The minimal applied radius of the curves on the access road is  $R_{\min} = 55\text{m}$ . The longitudinal inclination of the levels is in the range of 0.5% to 13.0%.

Typical cross-sections of the road have fixed width, and they are with the following dimensions:

- Road lane.....  $2 \times 2.5 = 5.0\text{ m}$
- Shoulder.....  $2 \times 0.5 = 1.0\text{ m}$

**Total: 6.0 m**

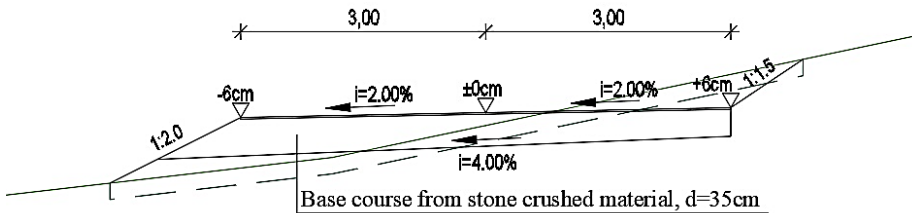


Figure 2. Typical cross – section in side cut

The embankment is planned to be constructed with a slope of 1:2. On steep slopes of 12%, the shaping of the hull would be performed with an auxiliary embankment (next to the scissors of the main one) with a crown width of 3.0 m (sufficient for the initial installation of the mechanization). The embankment would usually take place on the side of the main hull. After obtaining the width for filling in the main embankment greater than 3.0 m, the auxiliary embankment would be removed. The material from it would be used for the primary embankment.

The applied road structure will mainly serve only for securing the hull of the road during the delivery of the equipment for the construction of the windmills.

The adopted road construction is as follows:

- Base course from stone crushed material.....  $d = 35\text{ cm}$

## 2.1. LAYOUT PLAN AND LONGITUDINAL PROFILE OF THE ROAD

For a definite horizontal and vertical shaping of the route, geodetic surveys were done on an updated geodetic base  $M 1:1\ 000$ , which provides accurate data on the micro-location of the route. Therefore, the immediate withdrawal and construction of the road axis is a function of the limitations and conditions offered by the terrain in which it is traced.

During the design process of the layout plan, the recommendations of the equipment supplier are taken into consideration, as follows:

1. Dead-end roads are constructed or locations where loaded transports must turn around prior to delivery to the Installation Area. Turning Areas are required to avoid reverse driving. The turning areas for cranes and unloaded trucks are also considered.
2. Roads and junctions are designed to allow component deliveries from one direction; however, they also allow for access from both directions for crane relocation purposes. Therefore, Crane relocation vehicles can travel directly between each Hardstand. If not, mitigation methods must be mutually agreed upon.
3. Offloading the nacelle with self-offloading transport equipment may require that the Site Road be extended 35 m beyond the end of the Hardstand. The route is guided towards the zero-terrain line, ensuring that it at least enters the private plots.

During the levelling, fixed points are accepted as beginning parameters, such as the local road Stojakovo - Bogdanci and the endpoints of the location, the plateau of the windmills.

When choosing the elements of the layout plan, it is considered that the route is maximally integrated into the terrain configuration along its entire length.

The selected radii of the horizontal curves were made by the Investor's recommendations and the catalogue for specific terrain conditions.

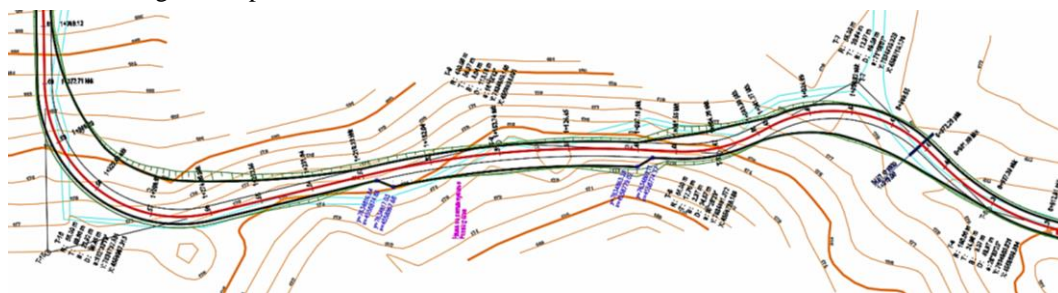


Figure 3. Layout plan with horizontal curves

Four crossroads have been organized on the entire wind farm for the roads, which are also turning points for blade delivery trucks. In addition, at a minimum distance of about 2 km, niches have been designed to allow the pass of heavy trucks for uninterrupted traffic.

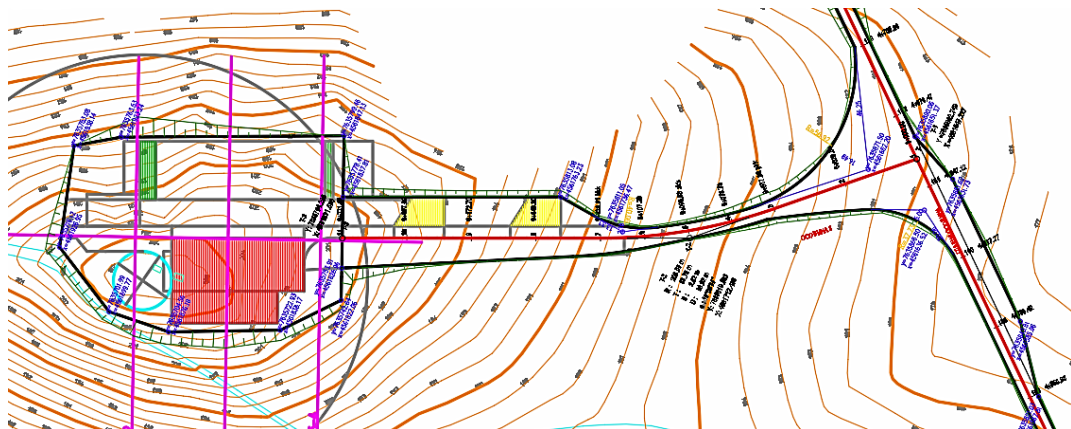


Figure 4. Layout plan of plateau



The plateau formation is designed according to the Contractor's needs and the construction organization. Four auxiliary cranes should be installed for installing the leading crane and storage space for the windmill blades.

The longitudinal slopes are within the allowed limits according to the valid regulations for road design, i.e., from 0.5% minimum for drainage to a maximum of 13.0%.

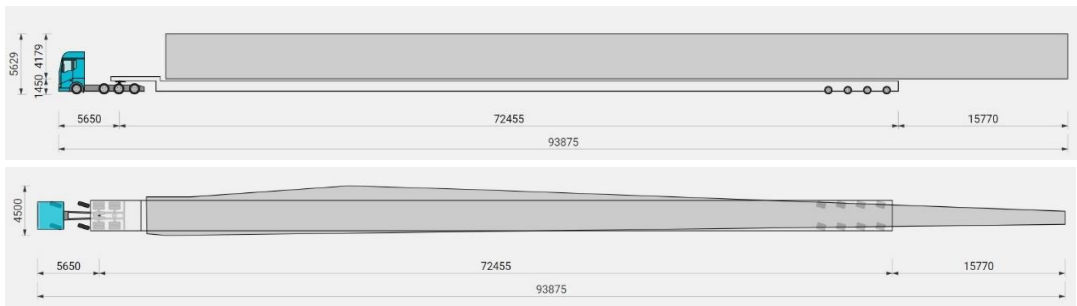
The radiuses of the vertical curves along the whole section are within allowed limits according to the catalogue for specific terrain conditions for road design and range from  $R_{\min} = 600\text{m}$  to  $R_{\max} = 25,000\text{m}$ .

Special consideration has been taken to avoid supporting structures when defining the longitudinal slopes.

## 2.2. RELEVANT DESIGN VEHICLES

The geometric elements in the design are made depending on the dimensions of the relevant vehicles that will deliver the equipment:

- Heavy freight vehicle with trailer and dimensions 78.0 x 2.5 m and a turning radius  $R = 55.0\text{ m}$
- Heavy freight vehicles with a trailer and dimensions 18.0 x 2.5 m and a turning radius  $R = 12.0\text{ m}$ .



*Figure 5. Overall length of vehicle*

### 2.2.1. Passability check for relevant design vehicles

Due to the significant length of the relevant vehicles, it was necessary to check the passability of the vehicle along the designed access road and plateau.

The analysis was made by applying a track curve, which established that the defined design elements in a layout plan and longitudinal profile provide adequate passability of the vehicle.

The pictures below show the locations along the route with border elements in a layout plan with the position of the relevant vehicle in motion.

In the place where the vehicle gauge exits from the road, the slopes must be raked in the scope so that there is no gap between the stomach of the vehicle and the existing ground.



Figure 6. Maps satellite image for passability check with tire tracks of tractor and trailer



Figure 7. Maps satellite image for passability check with area covered by vehicle combination

### 2.3. DRAINAGE

A hydrological analysis was made for the planned location according to the current location precipitation, and the types and positions of the culverts were defined from it.

For the most part, the road's route is guided along the ridge of the hill. For that reason, there are no large catchment areas, which results in the need for pipe culverts with a diameter of Ø300 to Ø600.

Due to the culverts' easier maintenance (cleaning), they are all standardized on diameter Ø1000.

The small number of vehicles planned to move on the road allows pouring surface water into the excavation and discharging it when the profile is in the embankment. This overflow of water along the road is allowed on sections with a maximum length of 50 m. In places where longer sections of 50 appear in the excavation, the application of trapezoidal ditches with a bottom width of 35 cm is mandatory.

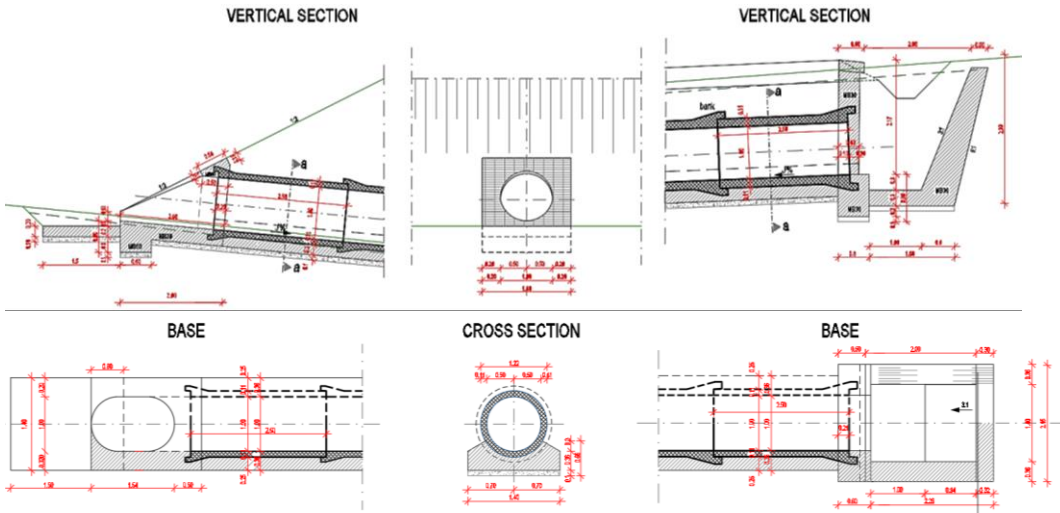


Figure 8. Pipe culvert Ø1000 in vertical section and base

### 2.3. QUANTITIES

The quantities determined for the roads are calculated with a standard procedure using the Trapezoidal Method, which is based on the assumption that the mid area of a pyramid is half the average area of the ends. The determination of the volumes in the part of the plateau is made by subtracting the benchmark area (terrain) concerning the projected area (bed and slopes). By calculating the volumes for the plateau, as the most significant quantities to be calculated, the areas for excavation or embankment in layers can be defined. This way of presenting the surfaces enables a more precise construction organization. It can be specified in layers as far as it corresponds to the available mechanization of the contractor.

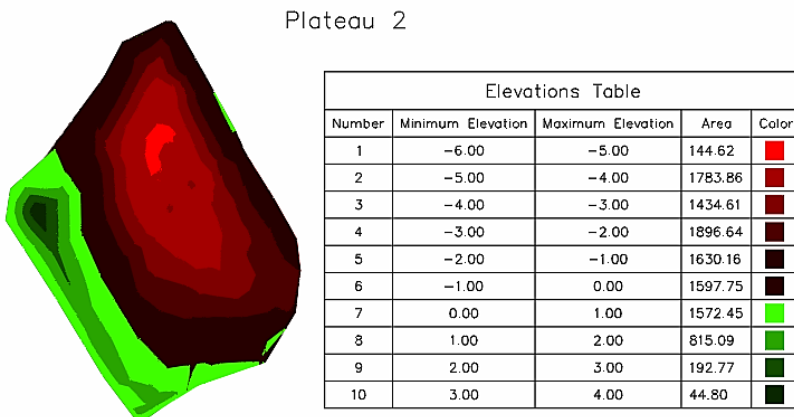


Figure 9. Graphic representation of volumes for plateau 2

### 3. CONCLUSION

We go beyond the standard tracing method by designing this type of road. Instead, the road elements are conditioned by the defined relevant vehicle, the terrain configuration, and the construction organization.

This way of designing and organizing a construction site can be applied for a significantly lower volume of construction activities and a significantly lower traffic volume. Although the relevant traffic here is minimal, it still significantly influences the choice of structural elements. This proves that even the seemingly easy macadam road should be designed at the highest level.

When designing and constructing access roads to a wind farm, the cost of the distributed equipment should also be considered as it significantly complicates the project. Any mistake made by the route designer can result in significant distribution problems, which may eventually cause millions of unforeseen costs (an impossibility for free maneuvers of the vehicle, damage to the equipment - blades, windmill body, turbine, etc.).

### LITERATURE

- [1] Wallasch AK, Lüers S., Rebennack S., Ekkert M. 2013 *Kostensituation der Windenergie an Land in Deutschland Deutsche WindGuard*
- [2] Krohn S., Morthorst PE., Awerbuch S. 2009 *Economics of Wind Energy European Wind Energy Association*
- [3] Siemens Gamesa Renewable Energy, 2021 *Site Specific Requirements General Part*
- [4] Bild Urban, 2021 *Main design for wind farm in Bogdanci – access roads*
- [5] Drumnahough Wind Farm, 2020 *Drumnahough Wind Farm Planning Documents*
- [6] Redington Wind Farm Project, 2006 *Basis of Design for the Roadways to Access Wind Turbines*
- [7] Nordex sales documents, 2017 *Transport, access roads and crane requirements for the K08 delta wind turbines*