



UNIVERSITY OF MONTENEGRO
FACULTY OF CIVIL ENGINEERING



THE NINTH INTERNATIONAL CONFERENCE
CIVIL ENGINEERING - SCIENCE & PRACTICE

GNP 2024 PROCEEDINGS



Kolašin, March 2024



UNIVERSITY OF MONTENEGRO



FACULTY OF CIVIL ENGINEERING

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



GNP 2024 PROCEEDINGS

KOLAŠIN, 5-9 MARCH 2024

GNP 2024 PROCEEDINGS

Publisher: **UNIVERSITY OF MONTENEGRO
FACULTY OF CIVIL ENGINEERING**

For Publisher: **Prof. dr Vladimir Božović**

Editors-in-Chief: **Prof. dr Marina Rakočević**

Editorial board: **Prof. dr Miloš Knežević
Prof. dr Marina Rakočević
Assist. Prof. dr Jelena Pejović**

Technical editing: **Boris Jevrić**

Cover photo by: **Milena Markolović**

CIP - Каталогизација у публикацији
Национална библиотека Црне Горе, Цетиње

ISBN 978-86-82707-36-3
COBISS.CG-ID 28528644

All rights reserved by Publisher and Authors



GNP 2024 SPONSORS

Co-Organiser of the Conference

ENGINEERS CHAMBER OF MONTENEGRO, CIVIL ENGINEERS CHAMBER
Podgorica, Montenegro

Gold Sponsor

CRBC – China Road and Bridge Corporation Montenegro Branch, Podgorica,
Montenegro

Silver Sponsors

CDS PROJECT, Podgorica, Montenegro
SIKA SRBIJA, Šimanovci, Serbia

Bronze Sponsors

ADING AD, Skopje, North Macedonia
BRIV CONSTRUCTION, Kotor, Montenegro
CEMEX MONTENEGRO, Podgorica, Montenegro
FREYSSINET SRBIJA, Belgrade, Serbia
INSTITUT ZA GRAĐEVINARSTVO, Podgorica, Montenegro
MONTEPUT – PJ AUTOPUT BAR-BOLJARE, Podgorica, Montenegro
NESHVYL, Belgrade, Serbia
STRABAG, Podgorica, Montenegro
VEKOM GEO, Belgrade, Serbia
VIGORIS ECOTECH, Podgorica, Montenegro

GNP 2024 SPONSORS

Friends of the Conference

C GROUP, Podgorica, Montenegro
CG RAD, Podgorica, Montenegro
GEOPROJEKT, Podgorica, Montenegro
MONTING ENGINEERING, Bitola, North Macedonia
MPMA - Montenegrin Project Management Association, Podgorica, Montenegro
M SOLUTIONS, Podgorica, Montenegro
PARS, Belgrade, Serbia
PEIKKO SLOVAKIA, Slovakia
PROFESSOR ARSENIJE VUJOVIĆ FOUNDATION, Podgorica, Montenegro
TD RADING, Skopje, North Macedonia
TENSAR INTERNATIONAL S.R.O CZECHIA, Czechia
WATER ADMINISTRATION GOVERNMENT OF MONTENEGRO, Podgorica, Montenegro

Donors

AGENCY FOR ELECTRONIC COMMUNICATIONS AND POSTAL SERVICES,
Podgorica, Montenegro
INSTITUTE FOR STANDARDIZATION OF MONTENEGRO, Podgorica, Montenegro
IRD ENGINEERING LTD, Podgorica, Montenegro
MMCERT - MMINSTITUT, Kotor, Montenegro
NIK COM, Nikšić, Montenegro
RG GROUP, Podgorica, Montenegro
SINTEK INZENERING DOOEL, Skopje, North Macedonia

Supported by

UNIVERSITY OF MONTENEGRO
MINISTRY OF TRANSPORT AND MARITIME AFFAIRS, Montenegro
13 JUL - PLANTAŽE, Podgorica, Montenegro
JU CENTAR ZA KULTURU KOLAŠIN, Montenegro
KOTOR MUNICIPALITY, Montenegro
ULCINJ MUNICIPAL ASSEMBLY, Montenegro

GNP 2024 Scientific Committee

INTERNATIONAL SCIENTIFIC BOARD

Professor Emeritus, Charalampos Baniotopoulos
Aristotle University of Thessaloniki, Thessaloniki, Greece
University of Birmingham, Birmingham, United Kingdom

Prof. Dr Paulo Barreto Cachim
University of Aveiro, Aveiro, Portugal

Assoc. Prof. Dr Mladen Bulić
University of Rijeka, Rijeka, Croatia

Prof. Dr Cristina Câmpian
Technical University of Cluj-Napoca, Cluj-Napoca, Romania

Assoc. Prof. Dr Saša Čvoro
University of Banja Luka, Banja Luka, Bosnia and Herzegovina

Prof. Dr Domagoj Damjanović
University of Zagreb, Zagreb, Croatia

Prof. Dr Szymon Dawczyński
Silesian University of Technology, Gliwice, Poland

Assoc. Prof. Dr Florim Grajčevci
University of Prishtina, Prishtina, Kosovo

Prof. Dr Luisa María Gil Martín
University of Granada, Granada, Spain

Prof. Dr Marcin Górski
Silesian University of Technology, Gliwice, Poland

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

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

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

Assoc. Prof. Dr Mitja Košir
University of Ljubljana, Ljubljana, Slovenia

Assoc. Prof. Dr Janusz Witalis Kozubal
Wrocław University of Science and Technology Wrocław, Poland

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

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

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

Prof. Dr Goran Markovski
Ss. Cyril and Methodius University, FCE, Skopje, North Macedonia

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

Prof. Dr Ildiko Merta
TU Wien, Wien, Austria

Assoc. Prof. Dr Radu Muntean
Transilvania University of Brasov, Brasov, Romania

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

Prof. Dr Igor Peško
University of Novi Sad, FTS, Novi Sad, Serbia

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

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

Assoc. Prof. Dr Neritan Shkodrani
Polytechnic University of Tirana, Civil Engineering Faculty, Tirana, Albania

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

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 Slaviša Trajković

University of Niš, Niš, Serbia

Prof. Dr Milan Veljković

Delft University of Technology, Delft, The Netherlands

Prof. Dr Guoxin Wang

Dalian University of Technology, Dalian, China

Prof. Dr Milan Trifković

University of Novi Sad, Novi Sad, Serbia

REVIEW BOARD

Prof. Dr Srđa Aleksić

University of Montenegro, Podgorica, Montenegro

Prof. Dr Ivana Banjad Pečur

University of Zagreb, Zagreb, Croatia

Assist. Prof. Dr Nikola Baša

University of Montenegro, Podgorica, Montenegro

Assist. Prof. Dr Željka Beljkaš

University of Montenegro, Podgorica, Montenegro

Prof. Dr Miroslav Bešević

University of Novi Sad, FCE Subotica, Subotica, Serbia

Prof. Dr Meri Cvetkovska

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

Assist. Prof. Dr Ivana Čipranić

University of Montenegro, Podgorica, Montenegro

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

Prof. Dr Đorđe Ladinović
University of Novi Sad, FTS, Novi Sad, Serbia

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

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

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

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

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

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

Assoc. Prof. Dr Milivoje Rogač
University of Montenegro, Podgorica, Montenegro

Assoc. Prof. Dr Snežana Rutešić
University of Montenegro, Podgorica, Montenegro

Prof. Dr Goran Sekulić
University of Montenegro, Podgorica, Montenegro

Assist. Prof. Dr Nina Serdar
University of Montenegro, Podgorica, Montenegro

Prof. Dr Boško Stevanović
University of Belgrade, Belgrade, Serbia

Assoc. Prof. Dr Radmila Sindić Grebović
University of Montenegro, Podgorica, Montenegro

Prof. Dr Milan Trivunić
University of Novi Sad, FTS, Novi Sad, Serbia

Assoc. Prof. Dr Merima Šahinagić-Isović
University Džemal Bijedić, Mostar, Bosnia and Herzegovina

Prof. Dr Mladen Ulićević
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

Assoc. Prof. Dr Slobodan Živaljević
University of Montenegro, Podgorica, Montenegro

Prof. Dr Ljiljana Žugić
University of Montenegro, Podgorica, Montenegro



**9TH INTERNATIONAL CONFERENCE
CIVIL ENGINEERING - SCIENCE AND PRACTICE**

KOLAŠIN, 5-9 MARCH 2024

TABLE OF CONTENTS

INVITED LECTURES 1

Svetlana Brzev

**SEISMIC DESIGN AND CONSTRUCTION OF REINFORCED CONCRETE
BUILDINGS - LESSONS LEARNED FROM THE 1979 MONTENEGRO AND
THE 2023 TÜRKIYE EARTHQUAKES 3**

Junlin Heng, Jiaxin Zhang, Sakdirat Kaewunruen and Charalampos Baniotopoulos

**ARTIFICIAL INTELLIGENCE-ASSISTED CIVIL ENGINEERING:
DIGITAL TWINS FOR THE WIND ENERGY INFRASTRUCTURE 23**

Nenad Ivanišević and Predrag Petronijević

CLAIMS AND DISPUTE RESOLUTIONS ON CONSTRUCTION PROJECTS 33

Srđan Janković

**PROBABILISTIC SEISMIC ANALYSIS OF REINFORCED CONCRETE
STRUCTURES 49**

*Goran Jekic, Veronika Shendova, Roberta Apostolska, Aleksandar Zhurovski, Aleksandar Zlateski
and Elena Delova*

**BUILDING SEISMIC RESILIENT SOCIETY IN NORTH MACEDONIA – IZHS'
EXPERIENCE 69**

Anastasia Kiratzi and Nikolaos Vavlas

**THE SEISMICITY OF MONTENEGRO WITHIN THE CONTEXT OF CURRENT
SEISMOLOGICAL TRENDS 85**

Mitja Košir

**THE ROLE AND IMPORTANCE OF CLIMATE CHANGE ADAPTABILITY IN
THE AGE OF HIGH-TECH BUILDINGS 93**

*Vlastimir Radonjanin, Mirjana Malešev, Zoran Brujić, Ivan Lukić, Slobodan Šupić and Vladan
Pantić*

**AN ENGINEERING CHALLENGE: REVITALIZING A 120-YEAR-OLD
CONCRETE WATER TOWER 111**

Roberta Santoro, Matteo Mazzeo and Rossella Laudani

**UNCERTAIN SEISMIC RESPONSE OF MASONRY STRUCTURES IN
OUT-OF-PLANE FAILURE MECHANISMS 131**

Mario Uroš, Josip Atalić, Marija Demšić, Maja Baniček, Marta Šavor Novak and Alen Kadić

IMPACT OF DEVASTATING EARTHQUAKES IN CROATIA IN 2020 143

THEORETICAL AND EXPERIMENTAL RESEARCH IN CIVIL ENGINEERING 151

Vasilije Bojović and Marina Rakočević

**ANALYTICAL AND NUMERICAL SOLUTION FOR FREE VIBRATIONS OF
LAMINATED COMPOSITE PLATES 153**

Ivica Boko, Jelena Lovrić Vranković, Ivana Uzelac Glavinić, Neno Torić and Mario Abramović

**THE INFLUENCE OF DIFFERENT ADHESIVE SYSTEMS ON THE SHEAR
STRENGTH OF GLUE LINES 165**

Milan Bursać and Svetlana Kostić

**EVALUATION OF YIELD SURFACES' ACCURACY FOR STEEL
I SECTIONS UNDER ELEVATED TEMPERATURES 173**

Marina Četković

STATIC ANALYSIS OF FGM PLATES USING LAYER WISE FINITE ELEMENT ... 181

Marina Četković

**LAYER WISE FINITE ELEMENT FOR MECHANICAL BUCKLING OF
FGM PLATES UNDER NON-UNIFORM EDGE LOADING 189**

Besim Demirović, Zijad Požegić and Edin Muratović

**ANALYSIS OF MATERIAL NONLINEARITY OF THIN PLATES ACCORDING
TO FINITE DIFFERENCE METHOD 197**

Ivana Drobnjak and Ljiljana Žugić

**NUMERICAL SOLUTION OF NONLINEAR EQUATION OF MOTION FOR
SINGLE DEGREE OF FREEDOM SYSTEMS USING MATLAB CODE 209**

Isidora Jakovljević, Nina Gluhović, Milan Spremić and Dušan Rajnović

**EXPERIMENTAL INVESTIGATION OF THE CONSTRUCTION JOINT
IN CONCRETE GROUND FLOORS 217**

Semso Kalac, Naja Zejnelagic, Djordje Djuricic and Dusko Lucic

**EXPERIMENTAL INVESTIGATION OF ALUMINUM WELDED LATTICE
GIRDERS 225**

Paulina Krolo, Lazar Lukačević, Antonio Bakran and Ivan Palijan

**EXPERIMENTAL STUDY OF T-SHAPE JOINT IN COLD-FORMED
THIN-WALLED STEEL STRUCTURES 233**

Marko Marinković, Christoph Butenweg

**EXPERIMENTAL CAMPAIGN ON SEISMIC BEHAVIOUR OF RC FRAMES
WITH ISOLATED MASONRY INFILL WALLS 241**

Ognjen Mijatović, Zoran Mišković, Ratko Salatić, Valentina Golubović-Bugarški and Matija Guzijan-Dilber

DEVELOPMENT OF A TOOL FOR MEASURING THE EFFECT OF SURFACE ROUGHNESS ON STEEL STRUCTURAL RESPONSE 249

Zoran Mišković, Siniša Savatović and Ljiljana Mišković

DIRECT LASER DYNAMIC DISPLACEMENT MEASUREMENT OF STRUCTURAL RESPONSE DURING TESTING 257

Hartmut Pasternak

BEHAVIOR OF PARTIAL STIFFENERS WITH AND WITHOUT END POSTS 265

Milivoje Rogač

RESISTANCE OF PATCH LOADED I-GIRDERS - CORRECTION FACTOR FOR LOAD LENGTH 273

Siniša Savatović, Zoran Mišković, Ratko Salatić and Marina Latinović-Krndija

ANALYTIC AND EXPERIMENTAL DETERMINATION IMPULSE RESPONSE OF SINGLE DEGREE OF FREEDOM SYSTEM 281

Maja Stanković, Milivoje Rogač and Vasilije Bojović

COMPARATIVE STRUCTURAL 2D ANALYSIS OF A WALL WITH OPENINGS IN RELATION TO MODELLING METHODS AND OPENING HEIGHT 289

Nikola Tomić, Anja Terzić and Dragan Bojović

COMPARISON OF DISTRIBUTED PLASTICITY APPROACHES FOR INELASTIC ANALYSIS OF REINFORCED CONCRETE FRAMES 297

STRUCTURAL DESIGN AND CONSTRUCTION 305

Jelena Bleiziffer

NEWLY PROPOSED PROCEDURE FOR DURABILITY DESIGN OF CONCRETE STRUCTURES IN THE 2ND GENERATION EUROCODES 307

Adriana Brandis, Mehmed Čaušević, Tanja Kalman Šipoš and Denis Brandis

COMPARISON OF NEW GENERATION OF EUROCODE 8 WITH CURRENTLY VALID NORM IN THE TERMS OF N2 METHOD 315

Mladen Muhadinović, Petar Subotić, Milivoje Rogač, Srđa Aleksić and Duško Lučić

COLUMN WEB IN TRANSVERSE COMPRESSION – CURRENT REGULATIONS AND RESEARCH 323

Nina Nikolić and Biljana Šćepanović

NUMERICAL ANALYSIS OF ALUMINIUM T-STUB CONNECTIONS 331

Tanja Nožica, Đorđe Jovanović, Drago Žarković and Andrija Rašeta

MOMENT-SHEAR INTERACTION IN ECCENTRICALLY BRACED FRAMES ... 339

Maja Ranisavljević, Jelena Dobrić, Aljoša Filipović and Milan Spremić

DESIGN CROSS-SECTION RESISTANCES OF PERFORATED COLUMNS UNDER COMPRESSION 347

<i>Sime Serdarevic, Dalibor Gelo, Nina Santek and Sanela Vojnovic</i> NUMERICAL ANALYSIS OF CONFINED MASONRY WALLS	355
<i>Bratislav Stipanić</i> ADVANCES IN BRIDGE REALIZATION	363
<i>Zlatko Zafirovski, Pero Cvetkovski, Vasko Gacevski, Ivona Nedevska Trajkova, Riste Ristov, Slobodan Ognjenovic and Marijana Lazarevska</i> STABILITY ANALYSIS OF PORTALS IN TUNNELS	371
SEISMIC RESISTANT STRUCTURES	379
<i>Nikola Baša and Jovan Furtula</i> SEISMIC ANALYSIS OF PRECAST REINFORCED CONCRETE FRAME STRUCTURES	381
<i>Andrija Djogovic and Nina Serdar</i> COMPARISON OF NONLINEAR SEISMIC BEHAVIOUR OF RC CURVED BRIDGE WITH THE EQUIVALENT STRAIGHT BRIDGE	389
<i>Radomir Folić, Damir Zenunović, Miloš Čokić and Boris Folić</i> DESIGN OF SHALLOW CONCRETE FOUNDATION IN SEISMIC REGIONS - METHODOLOGY	397
<i>Luisa María Gil-Martín and Enrique Hernández-Montes</i> THE EXTENSION OF THE YIELD DISPLACEMENT CHARTS	409
<i>Magdalena Jerkovic, Sime Serdarevic, Dalibor Gelo and Ivan Volaric</i> BEHAVIOR OF STEEL STRUCTURE IN SUPPORTING MASONRY STREET FACADES UNDER SEISMIC LOADING	415
<i>Vladimir Jovanović</i> COUPLED WALL SYSTEM SEISMIC SHEAR FORCE ANALYSIS	425
<i>Borko Miladinović</i> SEISMIC LOAD OF PILE-SUPPORTED STRUCTURE – REVIEW OF SEISMIC STANDARDS	433
<i>Borko Miladinović, Boris Jeremić and Zvonko Tomanović</i> PRELIMINARY ANALYSIS OF THE INFLUENCE OF CHANGING DISTANCE BETWEEN PILES ON HORIZONTAL ACCELERATION ELASTIC RESPONSE SPECTRA FOR PILE-SUPPORTED STRUCTURE	441
<i>Jelena Mirjanić, Andrija Rašeta, Vladimir Živaljević and Igor Džolev</i> INCORPORATING INFILL WALLS CONSIDERATION IN NONLINEAR STATIC PUSHOVER ANALYSIS OF RC FRAME BUILDING	449
<i>Ivan Mrdak, Marina Rakočević and Đorđe Lađinović</i> ASSESSMENT OF TORSIONAL IRREGULARITY PROVISIONS FOR BUILDINGS IN ACCORDANCE WITH EUROCODE 8	457

Giulio Proietti, Chiara Castino, Anna Maria Cicalese and Nicola Nisticò
**A PASSIVE CONTROL SYSTEM BASED ON DOUBLE U-SHAPED METAL
ELEMENTS: APPLICATIONS CASES, DESIGN AND DEVELOPMENTS 465**

Dani Rahimić and Emir Bajramović
DESIGN OF SEISMICALLY ISOLATED STRUCTURES 473

Petar Subotić, Mladen Muhadinović, Biljana Šćepanović and Duško Lučić
**THE FUTURE OF SEISMIC DESIGN OF STEEL STRUCTURES – PR EN 1998-1-1
AND PR EN 1998-1-2 481**

SPECIAL ISSUES OF STRUCTURAL DESIGN AND CONSTRUCTION 491

Ratka Djogovic and Mladen Ulicevic
**COMPARATIVE ANALYSIS OF STRUCTURAL SYSTEMS FOR ROOF
SURFACES WITH DOUBLE CURVATURE 493**

Goran Milutinovic, Ratko Salatic and Dusko Bobera
**ENGINEERING ASPECTS AND SENSITIVITY TO WIND LOAD OF A STRESS
RIBBON BRIDGE 501**

Luka Mirković, Teodora Popović, Katarina Mirković and Biljana Ivanović
**TECHNICAL SOLUTION OF AN INTERCHANGE OF A HIGH-SPEED ROAD
AND A MAIN ROAD IN ADVERSE TERRAIN CONDITIONS 509**

Stefan Mitrović, Milica Vidović, Ivan Ignjatović and Jelena Dragaš
EXPERIMENTAL TESTING OF 3D PRINTED CONCRETE TRUSS GIRDER 517

Predrag Presečki, Berislav Bošnjak and Petra Milić
**THICKNESS REDUCTION OF POST-TENSIONED SLABS DUE TO
PUNCHING SHEAR CRITERION 527**

Milan Spremić, Jelena Dobrić, Isidora Jakovljević and Nemanja Dinčić
**STRUCTURAL FIRE RESISTANCE DESIGN OF THE FOOTBALL
STADIUM ROOF STEEL STRUCTURE 535**

MODERN MATERIALS IN CIVIL ENGINEERING 543

Alma-Dina Bašić and Marijana Serdar
**CHANGES IN THE DURABILITY OF CALCIUM ALUMINATE CEMENT
BASED CONCRETE INDUCED BY SLAG ADDITION 545**

Marija Čosić, Ivana Banjad Pečur, Zvezdana Matuzić, Ivana Carević, Suzana Hozmec and Nina Štirmer
**PRECAST CONCRETE PRODUCTS WITH WOOD BIOMASS ASH AS
A PARTIAL CEMENT REPLACEMENT 553**

Vanja Gilja, Matea Flegar, Ivana Vladić-Kancir, Alma-Dina Bašić and Marijana Serdar
**OPPORTUNITIES FOR INSGITHS IN CEMENTITIOUS MATERIALS
THROUGH ADVANCED CHARACTERIZATION METHODS 561**

<i>Branka Mrduljaš, Katarina Didulica, Antonija Ocelić and Ana Baričević</i> MULTI-CRITERIA ANALYSIS OF WASTE FIBRE REINFORCED COMPOSITES	569
<i>Valentina Mustapić and Marijana Serdar</i> OVERVIEW OF REGIONAL MATERIALS FOR CO₂ STORAGE THROUGH CARBONATION	577
<i>Vladan Pantić and Slobodan Šupić</i> SUSTAINABLE UTILIZATION OF FLY ASH FOR THE PRODUCTION OF ECO-FRIENDLY MASONRY MORTAR	585
<i>Aleksandar Radević, Vladana Rajaković-Ognjanović, Marina Škondrić, Aleksandar Savić and Dimitrije Zakić</i> THE CHARACTERIZATION OF WASTE FROM THE DESULFURIZATION PROCESS FROM STEEL PLANT AND ITS POSSIBLE APPLICATION IN CEMENT COMPOSITE	593
<i>Mateusz Sitarz, Tomasz Zdeb, Tomasz Tracz, Sofija Kekez and Izabela Hager</i> INVESTIGATION OF ADHESION BETWEEN BASALT MINIBARS AND GEOPOLYMER MATRIX	601
<i>Marko Stojanović, Ksenija Janković, Dragan Bojović, Anja Terzić and Slobodan Šupić</i> PROPERTIES OF CONCRETE WITH CRUMB RUBBER IN RELATION TO ORDINARY AND AERATED CONCRETE	609
<i>Slobodan Šupić, Bojan Poletanović, Vlastimir Radonjanin, Mirjana Malešev, Ildiko Merta and Vladan Pantić</i> INFLUENCE OF ACCELERATED AGEING ON PULL-OFF STRENGTH OF CONCRETE PRODUCED WITH RECYCLED CONCRETE AGGREGATE AND BLENDED WITH HEMP FIBRES	619
<i>Ksenija Tešić, Ana Baričević and Marijana Serdar</i> INVESTIGATING THE INFLUENCE OF REINFORCED CONCRETE PROPERTIES ON CHANGE IN GPR SIGNAL	627
<i>Ivana Vladoić Kancir and Marijana Serdar</i> CHLORIDE-INDUCED CORROSION OF STEEL IN ALKALI-ACTIVATED MORTAR BASED ON SLAG AND RED MUD	635
<i>Donka Würth, Jure Galić and Martina Huljev</i> BEČARAC SQUARE AND MUSEUM IN PLETERNICA – COLOURED CONCRETE	643
RISK ASSESSMENT OF NATURAL AND ENVIRONMENTAL HAZARDS	651
<i>Senka Bajić, Dragoljub Veljović and Borko Bulajić</i> PHYSICAL ACTIVITY AS A TYPE OF EMERGENCY EXERCISE FOR ENHANCING THE EMERGENCY RESPONSE AND PREPAREDNESS PHASES OF A DISASTER	653

<i>Olga Čalasan, Ivana Čipranić, Milena Ostojić and Marija Jevrić</i> DETERMINATION OF DAMAGE FOR FLOOD RISK ASSESSMENT IN MONTENEGRO	661
<i>Meri Cvetkovska and Milica Jovanoska Mitrevska</i> FIRE HAZARD AND FIRE RISK ASSESSMENT OF URBAN AREAS IN NORTH MACEDONIA	669
<i>Marko Marinković, Matija Bošković, Filip Đorđević, Nemanja Krtinić and Željko Žugić</i> APPLICATION OF TWO SEISMIC RISK ASSESSMENT METHODOLOGIES ON THE DATA SET OF SCHOOL BUILDINGS IN SERBIA	677
<i>Ivana Mitrović</i> ON THE HYDROPOWER PLANTS AND THEIR IMPACT ON ENVIRONMENT – CASE STUDY: HYDROPOWER PLANTS DJERDAP	685
<i>Nina Serdar and Jelena Pejović</i> NATIONAL SEISMIC RISK ASSESSMENT FOR MONTENEGRO	693
<i>Ljuban Tmušić, Kristina Palajsa and Biljana Medenica</i> DISASTER RISK REDUCTION IN MONTENEGRO	703
<i>Milan Trivunić, Željko Jakšić, Dušanka Plazina Pevač, Igor Peško and Vladimir Mučenski</i> DATA COLLECTION ON HIGH-RISE BUILDINGS	711
MAINTENANCE, RETROFITTING AND STRENGTHENING OF STRUCTURES	719
<i>Marcin Gorski</i> IDENTIFICATION OF BLIND DEFECTS IN HARD-TO-REACH AREAS WITH AUTOMATED ROBOTIC DIAGNOSTIC TOOLS	721
<i>Ilija Lalošević</i> PROTECTION OF THE BUILT HERITAGE OF CULTURAL-HISTORICAL REGION OF KOTOR ON THE WORLD HERITAGE LIST AFTER MONTENEGRO 1979 EARTHQUAKE	729
<i>Paulo Šćulac and Matej Cukarić</i> EXPERIMENTAL ANALYSIS OF STRENGTHENED SCALED POINTED ARCHES	737
<i>Sinisa Visnjic, Lucija Delic and Luka Sekulic</i> DIMENSIONING OF THE STONE COVERING ON PROJECT RECONSTRUCTION OF THE MEASURING PROFILE "DUKLOV MOST"	747
STRUCTURAL MONITORING AND PERFORMANCE ASSESSMENT	755
<i>Milovan Bjelica and Vladimir Zotović</i> THE INFLUENCE OF AIR TEMPERATURE AND WATER LEVEL IN RESERVOIR ON THE DAM STABILITY	757

Dragan Kostić, Todor Vacev, Danijela Đurić Mijović and Miloš Milić
**IMPORTANCE OF CONSISTENT DESIGN, CONSTRUCTION, AND
MAINTENANCE OF STRUCTURES FOR THEIR SAFETY THROUGH
THE CASE OF CRANE RUNWAY COLLAPSE 763**

Marina Latinović Krndija, Gordana Broćeta, Anđelko Cumbo, Žarko Lazić and Saša Čvoro
**PRESTRESSED BEAM DAMAGE PROBABILITY ESTIMATION
THROUGH EIGENFREQUENCY MEASUREMENTS 771**

Milutin Pejović, Vladan Bošković, Mileva Samardžić-Petrović and Branko Milovanović
**LANDSLIDE GEODETIC MONITORING USING STATIC GNSS SURVEY AND
IWST METHOD 779**

**PLANNING, DESIGN AND CONSTRUCTION OF ROADS AND
RAILWAYS 787**

Daniel Cammarata, Andre Dubrall, Kalliopi Fotiadou and Leo Kuljanski
**ADVANCED DESIGN METHODOLOGY FOR THE PREDICTION OF
THE EV2 DEFORMATION MODULUS INCLUDING STABILIZING GEOGRID ... 789**

Milena Čojbašić
**AN OVERVIEW ON THE PRELIMINARY DESIGN OF CONSTRUCTION
ORGANISATION AND TECHNOLOGY FOR THE BRIDGE NO. 15 ON
BAR-BOLJARE HIGHWAY, MATEŠEVO-ANDRIJEVICA SECTION 797**

Marija Ivanović, Zoran Stojadinović, Dejan Marinković, Nevena Simić and Đorđe Nedeljković
**THE PROFESSIONALS' PERSPECTIVE ON THE CAUSES OF DELAY IN THE
SREBIAN ROAD INFRASTRUCTURE PROJECTS 805**

Panta Krstić, Milan Marinković and Nikolina Čirić
**COMPARISON OF ANALYTICAL AND NUMERICAL METHODS FOR
DETERMINING STRESSES IN CONCRETE PAVEMENTS DUE TO
TRAFFIC LOADING 813**

Ramona Petrović, Igor Peško, Mila Svilar and Nikola Banjac
**ESTIMATION OF COST AND DURATION OF ROAD CONSTRUCTION
USING ARTIFICIAL INTELLIGENCE 821**

Teodora Popović
**ADVANTAGES OF TURBO ROUNDABOUT IN RELATION TO CLASSIC
TWO-LANE ROUNDABOUT 833**

*Riste Ristov, Slobodan Ognjenović, Zlatko Zafirovski, Vasko Gacevski, Ivona Nedevska Trajkova
and Vlatka Kedioski*
**ROAD SAFETY INSPECTION IN THE FUNCTION OF DETERMINING
UNSAFE ROAD LOCATIONS 841**

CIVIL ENGINEERING AND SUSTAINABLE DEVELOPMENT .. 849

- Tiana Milović, Mirjana Laban, Anka Starčev-Ćurčin and Vesna Bulatović*
**CIRCULAR ECONOMY AND ITS BARRIERS TO IMPLEMENTATION IN THE
CONSTRUCTION SECTOR 851**
- Luka Pajek, Jaka Potočnik, Mitja Košir, Ivana Čipranić and Marija Jevrić*
**AN OVERVIEW OF OVERHEATING PREVENTION MEASURES IN
MONTENEGRIN RESIDENTIAL BUILDINGS BASED ON OCCUPANT
SURVEY RESULTS 859**
- Goce Prangovski, Suzana Arangelovska and Nikola Trpeski*
WASTE ASH FROM COMBUSTED WOOD BIOMASS IN CONCRETE 867
- Milena Senjak Pejić, Mirjana Terzić, Dragana Stanojević, Igor Peško, Maja Petrović, Mirna
Kapetina and Vladimir Mučenski*
**ESTIMATING QUANTITIES OF CONSTRUCTION AND DEMOLITION WASTE
FOR RECYCLING USING MACHINE LEARNING MODELS 875**
- Siniša Višnjić, Saveta Đuričić and Branka Peruničić*
VARIANT SOLUTIONS OF MICRO HYDROPOWER PLANT „OTILOVIĆI” 883

WATER ENGINEERING 891

- Emina Hadžić and Hata Milišić*
**INTEGRATED APPROACH TO WATER RESOURCES MANAGEMENT IN
URBAN AREAS 893**
- Marijana Milić, Goran Jeftenić, Ljubomir Budinski and Danilo Stipić*
**APPLICATION OF GMS FOR SIMULATION OF GROUNDWATER
LEVEL LOWERING 901**
- Milena Ostojić, Ivana Čipranić, Goran Sekulić and Olga Čalasan*
**IMPACT OF TORRENTIAL WATERCOURSES ON THE STABILITY OF
BRIDGE PIERS: EXAMPLES FROM MONTENEGRO 909**
- Goran Sekulić, Ivana Čipranić, Olga Čalasan and Milena Ostojić*
THE GENERAL STATE OF WATER RESOURCES IN MONTENEGRO 917
- Bledar Sina and Gëzim Hasko*
**MONITORING OF TIDE GAUGES IN THE REPUBLIC OF ALBANIA AND
ANALYSIS OF THEIR DATA 925**
- Siniša Višnjić and Saveta Đuričić*
**REVITALIZATION ANALYSIS OF HYDROPOWER PLANT
„RIJEKA CRNOJEVIĆA” 933**
- Siniša Višnjić, Saveta Đuričić and Stevan Popović*
**REVITALIZATION ANALYSIS OF MONTENEGRO'S FIRST MICRO
HYDROPOWER PLANT „PODGOR” 941**

GEOLOGY, HYDROGEOLOGY AND GEOTECHNICS IN CIVIL ENGINEERING 949

Aleksej Aniskin, Božo Soldo, Khrystyna Moskalova and Matija Orešković
CALCULATION OF THE LIMIT STATE OF EQUILIBRIUM OF ANISOTROPIC SOIL BY GRAPHIC METHODS 951

Nikola Čađenović and Ivan Maretić
LIQUEFACTION POTENTIAL OF THE TERRAIN ALONG THE MONTENEGRIN COAST 959

Nikolina Ćirić and Panta Krstić
STRUCTURAL-TECTONIC AND GEOTECHNICAL ASPECTS OF FRACTURE TESTING 967

Borut Macuh, Sašo Kos and Tamara Bračko
RETAINING STRUCTURE PK-24 AS A PART OF RECONSTRUCTION OF THE G2-108 HRASTNIK - ZIDANI MOST ROAD 975

Ajibola Rasaq Lawal, Tomasz Kania, Janusz Vitalis Kozubal and Matylda Tankiewicz
FIBER CONTENT AS A DETERMINANT OF SOIL MIXING QUALITY: METHOD AND ANALYSIS 983

Denis Veliu, Slobodan Živaljević and Goran Mijajlović
DETERMINISTIC APPROACH OF STABILITY ANALYSIS FOR ROCK WEDGE FAILURE 991

Janusz Vitalis Kozubal and Piotr Wyborski
EXPLORING THE RELATIONSHIP BETWEEN GEOSTATISTICAL FEATURES AND MOISTURE IN THE ANALYSIS OF COHESIVE SOIL FRACTURES 999

Ana Vojinović, Milica Popović, Maksim Matović, Nikola Mededović, Mila Krulanović, Sergej Poleksić, Marija Matović and Marina Mededović
SCOPE OF GEOLOGICAL RESEARCH WORKS ACCORDING TO THE RECOMMENDATIONS OF THE STANDARD MEST EN 1997-2:2018 (EUROCODE 7 - GEOTECHNICAL DESIGN - PART 2: GROUND INVESTIGATION AND TESTING) AND IMPLEMENTATION IN PRACTICE IN MONTENEGRO 1007

GEODESY IN CIVIL ENGINEERING 1015

Mehmed Batilović, Zoran Sušić, Marko Marković, Željko Kanović and Marijana Vujinović
INVESTIGATING THE EFFICACY OF IWST METHOD USING MONTE CARLO SIMULATIONS: CASE STUDY FOR PIPELINE OF PERUĆICA HYDROELECTRIC POWER PLANT 1017

Eduart Blloshmi, Bilbil Nurce and Oltjon Balliu
BUILDING THE GEODESIC NETWORK FOR THE CITY OF BERAT THROUGH GNSS SURVEYS 1027

<i>Tanja Đukanović, Sanja Tucikešić, Branko Božić, Ankica Milinković and Radovan Đurović</i> GEODETIC DEFORMATION MONITORING USING THE GNSS METHOD OF THE MEĐEDA EARTH DAM	1037
<i>Slavica Ilijević, Sanja Grekulović, Miljana Todorović-Drakul and Bogdan Bojović</i> REVIEW OF METHODS FOR DETERMINING THE GRAVITATIONAL EFFECT OF TOPOGRAPHIC MASSES	1045
<i>Igor Kovačević, Radovan Đurović, Gojko Nikolić, Vladimir Petrović and Sanja Tucikešić</i> DATABASES AND RECORDS OF PROPERTY AND NEW PLANTINGS IN THE COMPANY “13. JUL – PLANTAŽE” USING OPEN-SOURCE PLATFORM QGIS	1053
<i>Goran Marinković, Zoran Ilić, Žarko Nestorović and Anđelko Matić</i> ON THE RELATIONSHIP BETWEEN TWO STRAIGHT LINES BELONGING TO SAME PLANE	1061
<i>Marko Marković, Marina Davidović Manojlović, Marijana Vujinović, Mehmed Batilović and Đuro Krnić</i> ADVANCEMENTS IN ROAD MARKINGS DETECTION USING MOBILE MAPPING SCANNER-DERIVED POINT CLOUD	1067
<i>Branko Milovanović and Radovan Đurović</i> DESIGNING OF BRIDGE STRUCTURES MONITORING BY GEODETIC METHODS THE HORIZONTAL CONTROL NETWORK	1077
<i>Vesna Poslončec-Petrić, Iva Cibilić, Klara Zubović and Stanislav Frangeš</i> INTERACTIVE MAP OF WINE REGIONS OF THE REPUBLIC OF CROATIA	1085
<i>Milan Trifković, Miroslav Kuburić and Žarko Nestorović</i> ON THE GEODETIC NETWORKS FOR LARGE DAMS MONITORING	1093
<i>Marijana Vujinović, Vladimir Bulatović, Jasmin Čatić, Mehmed Batilović and Marina Davidović Manojlović</i> GAMIT/GLOBK: A REVIEW OF METHODOLOGY, APPLICATIONS, AND FUTURE PERSPECTIVES MANAGEMENT IN CIVIL ENGINEERING	1099
MANAGEMENT IN CIVIL ENGINEERING	1109
<i>Dajana Drljević, Lana Vukmirović Misić and Srdjan Topalović</i> LEGAL NATURE OF DAB / DAAB AND BINDING EFFECT OF ITS DECISION	1111
<i>Vasko Gacevski and Marijana Lazarevska</i> APPLICATION OF NETWORK PLANNING TECHNIQUE IN BUILDING CONSTRUCTION	1119
<i>Nenad Ivanišević and Nikola Prelević</i> COMPARATIVE ANALYSIS OF FIDIC’S CONDITIONS OF CONTRACT FOR CONSTRUCTION (FIDIC RED BOOK) - 1999 AND 2017 EDITIONS	1127

<i>Vlatka Kedioski, Marijana Lazarevska, Vasko Gacevski and Riste Ristov</i> ORGANIZATIONAL STRUCTURE OF CONSTRUCTION COMPANIES IN THE FUNCTION OF THEIR EFFICIENT OPERATION	1137
<i>Miloš Knežević</i> THINKING OUTSIDE THE BOX - ARTIFICIAL INTELLIGENCE - ETHICAL ISSUES	1145
<i>Ivona Krulanović, Ivana Čipranić and Zeljka Beljkaš</i> PREDICTION OF WATER DEMAND IN WATER SUPPLY SYSTEMS USING ARTIFICIAL NEURAL NETWORKS	1153
<i>Željana Kužet, Selena Samardžić, Vladimir Mučenski and Robert Lakatoš</i> NOISE EXPOSURE ASSESMENT FOR EXCAVATOR OPERATORS	1161
<i>Marijana Lazarevska, Vasko Gacevski and Zlatko Zafirovski</i> RANKING OF TOTAL TIME RESERVES FOR DETERMINATION OF THE CRITICAL PATH IN FUZZY NETWORK PLAN	1171
<i>Marijana Lazarevska, Vasko Gacevski and Zlatko Zafirovski</i> APPLICATION OF PRECEDENCE DIAGRAMMING FOR PLANNING OF A LOCAL ROAD RECONSTRUCTION	1179
<i>Dejan Marinković, Marija Ivanović, Nevena Simić and Nikola Knežević</i> A FRAMEWORK FOR PROGRESS MEASUREMENT BASED ON INTEGRATED MONITORING OF PREREQUISITES AND WORK PERFORMANCE	1187
<i>Snežana Mašović, Saša Stošić, Rade Hajdin, Nenad Pecić and Dragan Mašović</i> OPTIMIZATION OF BRIDGE MAINTENANCE POLICIES BASED ON SEMI-MARKOV DECISION PROCESS	1195
<i>Predrag Petronijević, Nenad Ivanišević, Nikola Knežević and Miljan Kovačević</i> THE FUTURE OF MACHINE CONTROL	1203
<i>Nevena Simić, Nenad Ivanišević, Đorđe Nedeljković, Marija Ivanović and Dejan Marinković</i> DATA COLLECTION AND DATABASE CREATION AS A DECISION SUPPORT IN THE INITIAL STAGES OF PROJECT DEVELOPMENT	1211
<i>Domagoj Šojat and Boris Uremović</i> PROPOSAL OF MATHEMATICAL MODEL FOR CALCULATING WEATHER CONDITIONS' IMPACT ON CONSTRUCTION WORKERS' PERFORMANCE	1219
<i>Dragana Stanojević, Vladimir Mučenski, Mirjana Terzić and Milena Senjak Pejić</i> CONSTRUCTION COST ANALYSIS OF COLD STORAGE WAREHOUSES	1227
<i>Srdjan Topalovic, Lana Vukmirovic Misic and Dajana Drljevic</i> FIDIC 2017 PROCEDURE FOR CLAIMS AND DETERMINATIONS	1235

BIM AND INFORMATION TECHNOLOGIES IN CIVIL ENGINEERING 1243

Nadica Angova Kolevska and Marija Vitanova

ASSESSING THE SEISMIC RESILIENCE OF A HEALTHCARE SYSTEM. CASE STUDY OF A PHI,, GENERAL HOSPITAL” STRUMICA 1245

Sonja Cherepnalkovska and Ljiljana Shoshkic

DIGITALIZATION IN CONSTRUCTION – BIM TECHNOLOGY 1255

SPATIAL, ARCHITECTURAL AND URBAN PLANNING AND DESIGN 1263

Bogdan Bojović, Zagorka Gospavić, Jelena Tatalović, Slavica Ilijević and Vladimir Petrović

ON THE DEPENDENCES OF HOUSING PRICES IN EURO AREA 1265

Ivana Ćipranić, Marija Jevrić, Olga Ćalasan and Milena Ostojić

REVIEW OF THE CURRENT STATUS OF URBAN DEVELOPMENT IN MONTENEGRO 1271

Ivana Ćirović, Jana Vasiljević, Aleksandar Pujović and Aleksandar Dimitrijević

MATHEMATICAL MODEL FOR RHYTHM IN ARCHITECTURE 1279

Marija Grujić, Anđela Knežević and Nikola Knežević

ORIENTATION DEPENDENT DIFFERENCES IN ENERGY BREAKDOWN FOR SINGLE OFFICES IN BELGRADE CONTINENTAL CLIMATE 1287

Anđela Knežević and Uroš Radosavljević

SHORT STUDIES IN TECTONIC ARCHITECTURE: A REVIEW ON POSTMODERN AND CONTEMPORARY BUILDINGS 1295

Arli Llabani and Freskida Abazaj

3D DOCUMENTATION OF CULTURAL HERITAGE USING TERRESTRIAL LASER SCANNING 1303

Ivana Miteska, Goran Mickovski, Ana Trombeva-Gavriloska and Teodora Mihajlovska

ADAPTIVE REUSE OF INDUSTRIAL FACILITIES USING ENERGY EFFICIENCY PRINCIPLES 1311

Marjan Petrović

TYPOLOGICAL CHARACTERISTICS OF RESIDENTIAL ARCHITECTURE IN NIŠ IN THE LATE MODERN PERIOD - A CASE STUDY 1319

Ivana Štimac Grandić and Iva Vodopija

ACCESSIBILITY OF FOOTBRIDGES: CASE STUDY OF THE PROVOMAJSKA OVERPASS IN POREČ 1327

Stefaneta Žarković and Dragan Žarković

EXAMPLE OF APPLICATION OF MODERN BUILDING STANDARDS: PROJECT OF A TOURIST AND HOSPITALITY COMPLEX "IMANJE KNJAZ" IN PODGORICA, MONTENEGRO 1337

EDUCATION IN CIVIL ENGINEERING	1345
<i>Paulo Cachim</i> LEARNING MAKING A LEARNING-GAME IN SUSTAINABLE CONSTRUCTION	1347
<i>Cristina Campian, Camelia Negrutiu, Maria Pop and Paul Pernes</i> THE CIVIL ENGINEERING CURRICULA HARMONIZATION PROCESS INSIDE THE EUROPEAN UNIVERSITY OF TECHNOLOGY EUT+	1359
<i>Szymon Dawczyński</i> THE SIGNIFICANCE OF THE PROFESSIONAL PROFILE MAP IN CONTEMPORARY CIVIL ENGINEERING EDUCATION	1367
<i>Milan Gocić, Ivana Čipranić, Marija Jevrić and Emina Hadžić</i> AN APPROACH TO THE CURRICULA INNOVATION IN THE CLIMATE-SMART URBAN DEVELOPMENT EDUCATION	1375
<i>Nadja Kurtović Folić and Svetlana Perović</i> THE ROLE OF ARCHITECTURAL EDUCATION IN CREATING A SUSTAINABLE FUTURE	1383
<i>Snežana Rutešić, Željka Beljkaš, Miloš Knežević, Marina Rakočević and Jelena Pejović</i> CLIMATE AND SUSTAINABILITY IN EDUCATION AND RESEARCH AT THE UNIVERSITY OF MONTENEGRO	1393
GNP 2024 AUTHORS	1401
PROFESSOR ARSENIJE VUJOVIĆ FOUNDATION	1443
CO-ORGANISER	1447
SPONSORS	1451



**THE 9th INTERNATIONAL CONFERENCE
"CIVIL ENGINEERING – SCIENCE AND PRACTICE"**

GNP 2024 – Kolašin, Montenegro, 5-9 March 2024

Marijana lazarevska¹, Vasko Gacevski², Zlatko Zafirovski³

**APPLICATION OF PRECEDENCE DIAGRAMMING FOR PLANNING
OF A LOCAL ROAD RECONSTRUCTION**

Abstract

Planning is essentially a way of mentally presenting projects in the future, and it is implemented through the creation of models (graphical, mathematical, etc.) through which the behaviour of the future real project is simulated in a changing environment. It implies the implementation of analyses with included risk and uncertainty for correct decision-making during the implementation of projects.

In modern construction, the realization of any more serious project cannot be imagined without the application of quality planning and management methods. Network models are an example of the most commonly used methods for planning of the implementation of complex and long-term projects. The most commonly used network models in construction are: Critical Path Method (CPM) and the PERT method (Project Evaluation and Review Technique). They are used for analysis of the project time duration, cost and resources. Both methods use a graphical representation of the project through an appropriately oriented network model composed of basic elements such as: activities, events, durations, costs, resources etc.

This paper gives an example of the application of Precedence diagramming for planning of a local road reconstruction, as an easy approach for determination of the total time duration of the project that gives a clear overview of the technology of construction in accordance with the general and specific conditions of the project and its environment.

Keywords

Precedence diagramming, planning, time analysis, road, reconstruction, network plan, critical path, technology of construction, project activities.

¹ Assistant Professor, Faculty of Civil Engineering, University „Ss. Cyril and Methodius“, Skopje, Republic of North Macedonia, marijana@gf.ukim.edu.mk.

² Teaching assistant, Faculty of Civil Engineering, University „Ss. Cyril and Methodius“, Skopje, Republic of North Macedonia, gacevski@gf.ukim.edu.mk.

³ Assistant Professor, Faculty of Civil Engineering, University „Ss. Cyril and Methodius“, Skopje, Republic of North Macedonia, zafirovski@gf.ukim.edu.mk.

1. INTRODUCTION

Planning is one of the most complex, difficult, sensitive and important conscious human activities in any area of his activity. It includes vision and assessment of all possible events and situations, that is, prediction of all activities resulting from the occurrence of possible events in the future. It is a complex process that implies an accurate and precise direction of action and decision-making, based on knowledge, experience and correct assessments.

Although it is complex process that is often accompanied by a large number of risks and uncertainties, planning is the basis for efficient and successful work of any company, regardless of the activity, type, size and characteristics of its organizational structure. Correct project planning leads to successful realization of the project goals.

The modern concept of the organization of the building construction process implies timely planning of all project activities, in terms of time and costs, as well as in terms of continuous coordination and control of all parameters that are necessary for quality construction of the structures, in the optimal time frame. and with the most favourable economic conditions.

The main goal of construction project planning is the management of all project activities, ensuring coordination, monitoring and control of their implementation, in order to achieve the defined goals. Appropriate prediction and planning of the construction projects allows a better division of work tasks, more rational application of construction machines, better use of working time and resources, increase in productivity and economy, reduction of losses in production etc. For construction projects, various techniques and methods can be applied that enable planning of: time, costs, quality, resources and risks.

2. NETWORK PLANNING TECHNIQUE

The technique of network planning enables adaptive management of the project realization process. This positively affects the facilitation of the exchange of information between the participants in the implementation of the project, their accuracy and reliability, and is an effective means of increasing the responsibility of executors and managers at all levels.

Using this technique, people who manage complex projects can foresee the problems in the execution of the project and perceive the critical things (activities) that can affect the deadline for the execution of the task. On the basis of the data obtained from the network diagrams, the execution of the activities within the planned deadlines, the engagement of the participants in the realization of the project and the material resources can be optimized in advance.

The technique of network planning uses sufficiently strict algorithms with the help of which the optimal (or close to optimal) solution is determined, the probability of the realization of individual parts of the project and the whole is forecasted. This technique provides a significant improvement in the quality of planning by looking for logical connections between activities during the realization of the plan, which ensures its placement on a realistic basis. In particular, it should be emphasized that the methods of network planning and management allow a precise estimation of costs, with which project managers can pay attention to critical activities and find a way to realize their principle ideas with which the end result would be: cost reduction and shortening the project implementation period.

3. PRECEDENCE DIAGRAMMING FOR TIME ANALYSIS

For planning of the time for the realization of projects, especially in construction, in addition to the critical path method and the PERT method, the so-called priority method (Precedence diagramming) has significant importance. The development of this method is due to the need to overcome some of the shortcomings that arise during the use of the critical path method and the PERT method, which mainly relate to: complicated network plans and ways of marking of the events, as well as the impossibility for graphically displaying activities that have overlapping beginnings and/or endings.

The Precedence diagram uses a block network plan to graphically display the realization of projects. The rules for displaying the project activities and for constructing the network plan are slightly different compared to the classical planning methods. Namely, with this method, the activities are presented as circles (or rectangles), and the technological and logical dependence between the activities is represented with the help of arrow-shaped lines.

Time analysis implies solving the network plan model, that is, calculation of the earliest and latest beginnings or ends of activities, time reserves, as well as critical activities and the critical path in the network plan. In the Precedence diagram several terms for the time are being used.

The earliest time when the activity "i" can start is called the Earliest Start Time and is marked with ES_i . When the activity "i" starts at the earliest start, it will be able to finish at the earliest possible moment, which is called the Earliest Finish Time and is denoted by EF_i . The moment in time when the activity "i" is finished at the end of the available time is called the Latest Finish Time and is marked with LF_i . When the activity ends at the latest, it means that it started late, and that moment in time is called the Latest Start Time and is marked with LS_i .

The code of the activity, which is defined in the first stage of the network planning technique (in the list of activities) is written in the upper quarter of the circle. The duration of the activity, expressed in appropriate time units, is written in the lower quarter of the circle. The earliest start and finish time of the activities are calculated according to the "forward method", from the first to the last activity in the network plan. The values of these time terms are entered in the left quarter of the circle. The latest start and finish time of the activities are calculated according to the "backward method", from the last to the first activity in the network plan. The values of these time terms are entered in the right quarter of the circle (Figure 1).

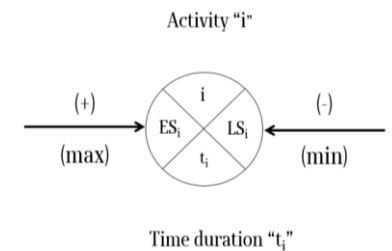


Figure 1. Graphical representation of a project activity in Precedence diagram

Activities that have equal values of earliest and latest finish time are called critical activities. The critical activities that connect the first to the last activity give the critical path of the network plan. The critical path determines the total duration for the realization of the project.

4. APPLICATION OF PRECEDENCE DIAGRAMMING FOR PLANNING OF THE LOCAL ROAD RECONSTRUCTION

This paper gives an example of the application of Precedence diagramming for planning of a local road reconstruction, as an easy approach for determination of the total time duration of the project that gives a clear overview of the technology of construction in accordance with the general and specific conditions of the project and its environment.

The process of planning the reconstruction of roads is very complex task, having in mind the many different activities that have to be taken into account, specific environmental conditions and requirements that have to be addressed, complex design requirements that have to be followed, the complexity of the type of works that have to be finished, the complexity of the technology of construction and the specific technical rules and requirements that cannot be ignored.

Although there are many tasks that should be finished when planning the reconstruction of roads, as a complex construction project, the example shown in this paper addresses some of them: the preparatory works (such as: organization of the construction site, setting up the laboratories on the site, geodetic marking of the route), main works related to the demolition of the existing asphalt layer of the road, curbs, gutters, protection fences and traffic signs), main civil engineering works related to the reconstruction of the road (subgrade, tampon layer, asphalt layer, concrete curbs, asphalt gutters, berms) and additional works related to slope protection, installation of traffic signs and protection fences. The works related to the installations located under the road surface are not part of the analysis, because the example was made according to the realistic design that did not include reconstruction of the installations.

All data that are used as inputs in the analysis for modelling of the Precedence plan are given in the Table 1: description of project activities, code, time duration of each activity expressed in days, and the technological and logical interconnection between activities.

Table 1. List of project activities for reconstruction of an existing local road

Description of activity	Code	Duration of activity	Previous activity
		t_i	
Site organization	1	3	/
Provision of a laboratory with the necessary equipment and conditions for field ongoing and control geotechnical, asphalt and concrete investigations	2	2	1
Traffic time regime	3	3	1
Geodetic marking, securing and staking the route	4	2	2, 3
Cross cutting of existing asphalt	5	1	4
Demolition of existing asphalt, with loading and transport of the material to a landfill	6	5	5
Demolition of existing concrete curbs by loading and transporting the material to a landfill	7	3	5

Demolition of existing gutters by loading and transporting the material to the landfill	8	3	5
Dismantling of the existing protective fence and traffic signs	9	2	6, 7, 8
Excavation of sub-base and earth material with loading and transport to a landfill	10	7	9
Demolition of existing shoulders from sub-base material	11	3	9
Construction of subsoil (under improved subgrade)	12	4	10, 11
Procurement, transport and execution of an improved subgrade the entire width of the substructure of the road with a thickness of 30 cm	13	7	12
Construction of subgrade	14	2	13
Procurement, transport and execution of subbase course from stone material 0-63mm	15	7	14
Procurement, transport and execution of concrete curbs	16	2	15
Preparation of asphalt base with spraying of cationic stabilized emulsion for connection of subbase with BNS	17	2	16
Procurement, transport and execution of bituminous bearing layer BNS 32 sA PmB 25-55/55 d=7cm	18	5	17
Construction of asphalt gutters	19	3	17
Preparation of asphalt base with spraying of cationic unstable emulsion for connection of AB with BNS	20	2	18, 19
Procurement, transport and execution of asphalt concrete AB – 16s PmB 45-80/65 d=5cm	21	5	20
Construction of shoulders with subbase material with thickness d=7cm with mechanical stabilizations	22	2	21
Construction of berms	23	2	22
Slope protections	24	2	22
Procurement, transport and installation of traffic signals and equipment	25	3	22
Installation on a protective barrier fence	26	5	23, 24, 25
Demobilization of the site	27	2	26

The project activities are defined in accordance to the optimal technology for reconstruction of a local road, located in the Republic of North Macedonia, with a total length of 3.00 km. For each project activity the previous activity has been defined, according to the adopted technology and organization of construction. The fact that some of the project activities can be realized at the same time, even though they are different type, gives the opportunity to achieve shorter time of construction. This approach should be followed whenever it is possible, because the statistics of already built roads in Republic of North Macedonia show that none of the major projects were finished as planned, neither on time, neither within the planned budget (taken from the official reports written by the Public Enterprise of State Roads). It is very important to plan the realization of different activities at the same time, in order to stay within the projected deadlines and to have some time reserves that can be used if some unplanned or unforeseen situations happen during the construction.

The time duration (t_{ij}) of each project activity (expressed in working days) is determined based on recorded historical data for the actual time required for their execution. In other words, the time of the activities is calculated by applying the construction norms and standards that are based on elementary engineering assessments and experiences on the way and time of the realization of activities in normal working conditions and environment. The normal execution time of the activities implies the application of standard work technology and an open work front, work in one (or more) shifts, with the most favorable work methods, and the optimal selection of construction tools and methods.

By following the logical and technological dependence between the defined project activities, a network plan has been constructed, the total time needed for the reconstruction of the local road was calculated and the critical activities and the critical path were obtained. The constructed technological model of the network diagram is shown on Figure 2. The project activities are graphically presented by their codes written in the circles, and the dependence between the activities is expressed by arrowed lines.

With the "forward" method, the earliest finish time of the activities were calculated, starting from the first to the last activity included in the network plan. The latest finish time of the activities were calculated by the "backward" method and these values are shown in Figure 3.

According to the calculation of the earliest and latest finish time of previously defined project activities it is obtained that the total time required for the reconstruction of the existing local road is 67 days. The critical activities and the critical path are also determinate and they are shown on Figure 3. The total time duration of construction projects has direct and multiple effects on the total investment costs. That is why the precise and proper planning is of significant importance for achieving the project goals and meet the project requirements. Furthermore, regular monitoring and control of the construction plans gives the possibility for taking adequate measures to maintain the planned dynamics, and that can significantly affect the cost for construction, increase the saving of financial resources during the construction, and increase the return on investment in the exploitation phase.

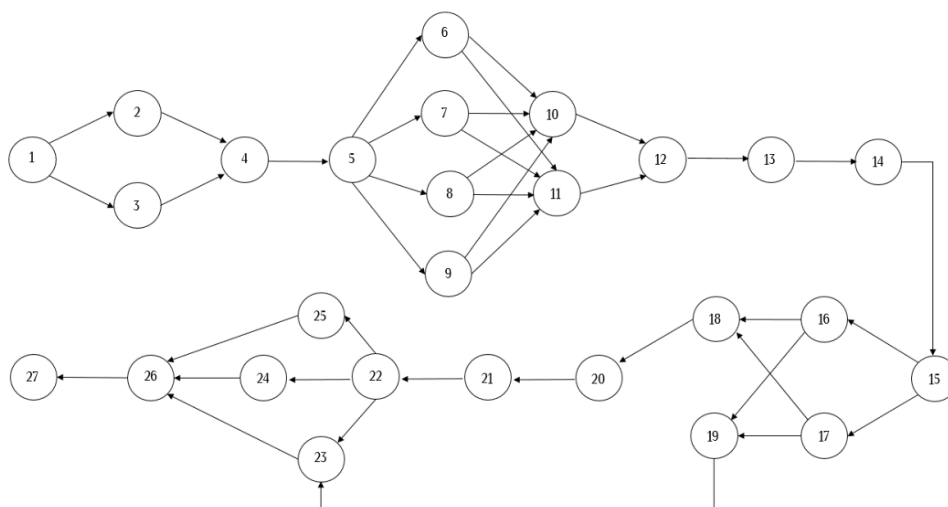


Figure 2. Model of network plan for reconstruction of an existing local road

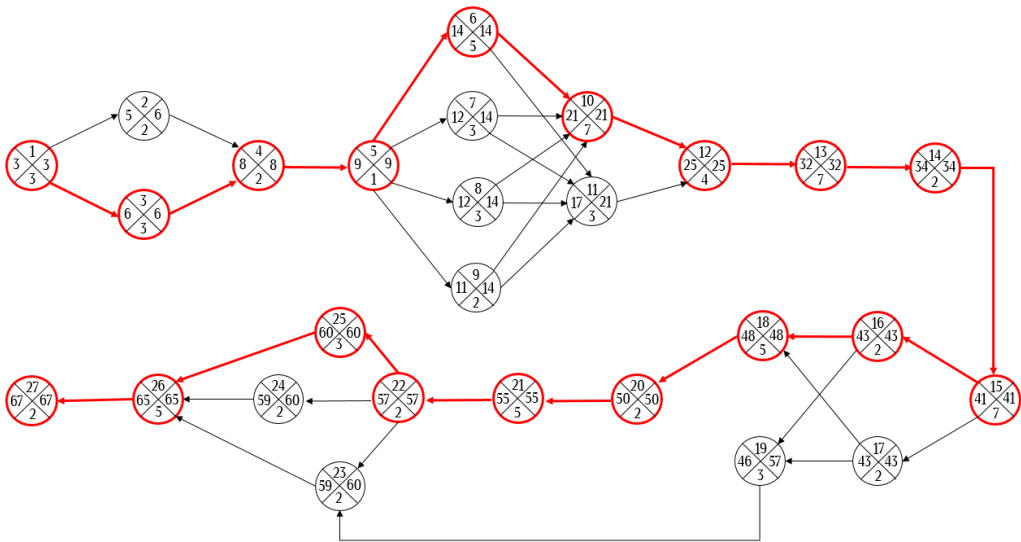


Figure 3. Graphical representation of the critical activities and the critical path in the network plan

5. CONCLUSIONS

This paper gives one example of application of network technique for planning of a reconstruction of a local road. It is possible to use a time-distance method for planning of road's construction, however, this method of planning does not offer the possibility of showing the connections and dependencies between project activities, and has poor transparency if the realization of a large number of activities needs to be planned. The precedence diagram, on the other hand, allows quick and easy change of the duration of activities and their dependence, whenever is needed. That why, the plan can be easily adapted to the real site conditions and all risks that might occur in every phase of the road life cycle.

The precedence plan, shown in this paper, takes into consideration the realization of major project activities that have to be precisely planned, monitored and coordinated in order to achieve the project deadline and budget. The possibility of occurrence of unforeseen events and situation during construction can lead to longer time of completion of the road project, and this can significantly increase the project costs. That is why several different plans should be analysed, all in accordance with the adopted technology and organization of construction, so that the plan that takes into consideration the parallel realization of works and gives the optimal time of completion, can be selected. All works should be continuously monitored and controlled, during the construction phase.

Planning of the realization of road projects is an extremely complex process, taking into account all the specifics and characteristics of the project, such as: the vast number of project activities that have to be carried out, the large amount of works that need to be completed, the duration of the life cycle of the projects, the multiplicity and diversity of the participants who are

involved in their implementation, the need for constant coordination of project tasks, the necessity of achieving previously set goals and strict requirements, etc.

It is known that road construction process, in general, is relatively poorly organized, which is most often a consequence of inadequate and/or insufficient preparations that precede the construction phase. In addition, practice shows that the technical and economic criteria for choosing the optimal solution, which are a basic prerequisite for achieving positive financial results, are not fully respected.

In order to ensure an efficient and effective construction of complex structures, such as roads and other infrastructural objects, it is necessary that the plans are ready before the start of the construction phase, so that any problems or difficulties which could cause a temporary stoppage of the construction and adversely affect the completion of the project can be predicted in advance. Given the fact that during the life cycle of road projects, numerous changes in the environment occur, and the projects themselves are subject to changes of different scope and character, it is necessary to include the changing nature of construction in the planning process. This means that planning must be treated as a continuous process that allows an easy adjustment of predictions to actual conditions, and that provides the opportunity for simple and continuous adjustment and modification of plans, where necessary. In addition, construction plans should be clear and allow a quick and easy review of all the data and information they contain, be realistic and made using accurate and unambiguous data, be precise and unambiguous in terms of showing time goals and the phases of construction, but also to be comprehensive, that is, the plan should cover all participants in the project and all contents and project activities.

LITERATURE

- [1] Baldwin A., Bordoli D.: Handbook for Construction Planning and Scheduling, John Wiley & Sons, 2014.
- [2] Branderberger J., Konrad R.: "Tehnika mreznog planiranja", ISPM, Beograd, 1968.
- [3] Jovanovic T., Jovanovic P., Djurdjevic P.: „Primena tehnike mreznog planiranja“, Uviverzitet u Beogradu, Masinski fakultet, Beograd, ISBN 86-7083-144-9, 1990.
- [4] Juraj M.: „Organizacija gradjenja“, Nacionalna i sveucilisna biblioteka u Zagrebu, Zagreb, 1994.
- [5] Kurij K.: "Izrada planova u graditeljstvo", Gradjevinska knjiga, Beograd, ISBN 978-86-395-0594-3, 2011.
- [6] Kurij K., Krstic G., Stamatovic M.: "Projekt menagment u gradjevinskoj praksi", SGITS, Beograd, 2000.
- [7] Lock D.: "Project management", Gower Press Limited, London, 1983.
- [8] Miller R.W.: "How to Plan and Control With PERT" HBR March–April 1962, p. 93.
- [9] Prašćević Ž.: "Upravljanje projektima", Građevinski calendar 1991, STITJ, Beograd, 1991.
- [10] Martinelli J. R., Milosevic Z. D.: Project Management ToolBox, Second Edition, John Wiley & Sons, 2016.