Association of Structural Engineers of Serbia
15th CONGRESS
ZLATIBOR, SEPTEMBER 6-8 2018

ASES INTERNATIONAL CONGRESS PROCEEDINGS

ASES
ДГКС

IN COOPERATION

SUPPORTED BY

Република Србија
Министарство
просвете, науке и
технолошког развоја

SPONSORS

PERI
ŠIRBEGOVIĆ INŽENJERING
PUT INŽENJERING
ADING sastojak svake građevine
peikko group
ENERGOPROJEKT
MARTINI GRADNJA D.O.O.
CRH
ARMONT

CIP - Каталогизација у публикацији
Библиотека Матице српске, Нови Сад

624+69(082)

ASSOCIATION of Structural Engineers of Serbia. Congress (15 ; 2018 ; Zlatibor)
ASES International congress proceedings [Elektronski izvor] / Association of Structural Engineers of Serbia, 15th Congress, September 6-8th, 2018, Zlatibor ; [editors Đorđe Lađinović, Zlatko Marković, Boško Stevanović]. - Beograd : Društvo građevinskih konstruktera Srbije, 2018 (Novi Sad : Grafički centar - GRID, Fakultet tehničkih nauka Univerziteta). - 1 elektronski optički disk (CD-ROM) : tekst, slika ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovnog ekrana. - Tiraž 250. - Radovi na srp. i engl. jeziku. - Bibliografija.

ISBN 978-86-6022-070-9

а) Грађевинарство - Зборници
COBISS.SR-ID 325104647

Izdavač:	**Društvo građevinskih konstruktera Srbije** Beograd, Bulevar kralja Aleksandra 73/I
Urednici:	prof. dr **Đorđe Lađinović** prof. dr **Zlatko Marković** prof. dr **Boško Stevanović**
Tehnički urednik:	doc. dr **Jelena Dobrić**
Tehnička priprema:	asist. **Nina Gluhović** asist. **Marija Todorović**
Gafički dizajn:	asist. **Tijana Stevanović**
Dizajn korica:	asist. **Tijana Stevanović**
Štampa:	**Grafički centar – GRID** **Fakultet tehničkih nauka Univerziteta u Novom Sadu**
Tiraž:	**250 primeraka**
	Beograd, septembar 2018.

POVODOM TRIDESETOGODIŠNJICE POSTOJANJA
A ZA NAROČITE ZASLUGE I USPEHE POSTIGNUTE
U RAZVIJANJU I UNAPREĐENJU GRAĐEVINSKOG
KONSTRUKTERSTVA I DOPRINOS UZDIZANJU
STRUČNIH KADROVA

ukazom broj 38 od 29. aprila 1983. godine

PREDSEDNIŠTVO SFRJ

ODLIKOVALO JE

SAVEZ DRUŠTAVA GRAĐEVINSKIH
KONSTRUKTERA JUGOSLAVIJE

ORDENOM RADA SA SREBRNIM VENCEM

Organizacioni odbor Kongresa:

Predsedništvo DGKS:

prof. dr Đorđe Lađinović, predsednik,
Aleksandar Bojović, potpredsednik,
prof. dr Zlatko Marković, generalni sekretar,
prof. dr Boško Stevanović, sekretar,
prof. dr Dragoslav Stojić,
prof. dr Mira Petronijević,
prof. dr Snežana Marinković,
v. prof. dr Danijel Kukaras,
doc. dr Branko Milosavljević,
doc. dr Selimir Lelović,
Duško Tomić,
Goran Vukobratović,
Goran Tadić,
Đorđe Pavkov,
Lazar Marković,
Branko Knežević,
Gojko Grbić.

Naučni odbor Kongresa:

prof. dr György Balazs (Mađarska),
prof. dr Radu Banchila (Rumunija),
prof. dr Dubravka Bjegović (Hrvatska),
prof. dr František Wald (Češka Republika),
prof. dr Milan Veljković (Holandija),
v. prof. dr Mirjana Vukićević (Srbija),
prof. dr Tatjana Isaković (Slovenija),
prof. dr Miloš Knežević (Crna Gora),
prof. dr Đorđe Lađinović (Srbija),
prof. dr Asterios Liolios (Grčka),
prof. dr Jože Lopatič (Slovenija),
prof. dr Duško Lučić (Crna Gora),
prof. dr Snežana Marinković (Srbija),
prof. dr Zlatko Marković (Srbija),
prof. dr Goran Markovski (Makedonija),
doc. dr Branko Milosavljević (Srbija),
prof. dr Primož Može (Slovenija),
prof. dr Tihomir Nikolovski (Makedonija),
prof. dr Doncho Partov (Bugarska),
prof. dr Radenko Pejović (Crna Gora),
prof. dr Mira Petronijević (Srbija),
prof. dr Milenko Pržulj (Slovenija),
prof. dr Vlastimir Radonjanin (Srbija),

CONTENTS

PRIZNANJE ZA ŽIVOTNO DELO U GRAĐEVINSKOM KONSTRUKTERSTVU DEJANU BAJIĆU, DIPL. INŽ……………………………………............................ 2

P-1 *Igor Petrović, Vladimir Stefanović* - POSLOVNI KOMPLEKS "SIRIUS" U BLOKU 43 NA NOVOM BEOGRADU…………………………………….. 6

P-2 *Aleksandar Trajković, Ivana Leposavić* - PROJEKAT KONSTRUKCIJE POSLOVNOG OBJEKTA U RAJIĆEVOJ……………………………….. 16

P-3 *Aleksandar Landović* - BEHAVIOR OF AXIALLY COMPRESSED COMPOSITE COLUMNS FOR EXPLOITATION AND ULTIMATE LOADS……………………………………... 25

P-4 *Veljko Koković, Dejan Bajić* - EXPERIMENTAL STUDY ON ULTIMATE CAPACITY OF HCS WITH RESTRAINED SUPPORT CONNECTION…. 35

P-5 *Miroslav Marjanović* - NONLINEAR ANALYSIS OF LAMINATED COMPOSITE PLATES AND SHELLS WITH DELAMINATIONS USING FINITE ELEMENT METHOD…………………………………………… 46

U-1 *Hugo Corres Peirreti, Freddy Ariñez Fernández, Julio Sánchez Delgado* - FIB MODEL CODE 2020 - CONTENT AND ONGOING PROCESS……... 58

U-2 *František Wald, Marta Kuříková, Lukáš Gödrich, Lubomír Šabatka, Jaromír Kabeláč, Drahoš Kojala* - MULTI LEVEL MEMBER AND CONNECTION DESIGN…………………………………………………. 73

U-3 *David Fernández-Ordóñez Hernández* - CONCRETE PREFABRICATION - LESSONS FROM THE PAST AND ADVANCES FOR THE FUTURE…. 85

U-4 *Milenko Pržulj* - SAVREMENE KONCEPCIJE I KONSTRUKCIJE SPREGNUTIH MOSTOVA………………………………………………. 97

U-5 *Meri Cvetkovska, Milivoje Milanović, Cvetanka Chifliganec* - FIRE RESISTANCE OF REINFORCED CONCRETE AND STEEL-CONCRETE COMPOSITE STRUCTURES……………………………... 123

S-43 *Bratislav Stipanić* - FACTORS OF IMPORTANCE FOR DURABILITY OF BRIDGES………………………………………………………………… 144

S-44 *Srđan Živković, Lela Mitić, Marko Milošević, Nenad Golubović, Matej Kosovel* - THE IMPROVEMENT OF CONSTRUCION SOLUTION FOR PREFABRICATED REINFORCED CONCRETE ELEMENTS CONNECTIONS…………………………………………………………... 154

S-45 *Miroslav Marjanović, Mira Petronijević* - PUSHOVER ANALYSIS OF BRIDGES INCLUDING SOIL-STRUCTURE INTERACTION EFFECTS.. 166

S-46 *Kemal Edip, Vlatko Šešov, Julijana Bojadžieva, Toni Kitanovski, Jordanka Čaneva, Dejan Ivanovski* - EFFECTS OF SOIL MODELLING IN SSI PROBLEMS……………………………………………………………….. 176

S-47 *Ivan Milićević, Svetlana Nikolić-Brzev* - SEISMIC RETROFITTING OF RC FRAME BUILDINGS BY ADDING NEW RC SHEAR WALLS………… 182

S-48 *Aleksandra Radujković, Igor Džolev, Đorđe Lađinović* - THE CHORD ROTATION CAPACITY OF REINFORCED CONCRETE COLUMNS UNDER MONOTONIC LOADING………………………………………… 194

S-49 *Marija M. Janakieska, Kiril Gramatikov, Manja K. Kuzman* - ARCHITECTS’ PERCEPTIONS OF ENGINEERED WOOD PRODUCTS IN MACEDONIA…………………………………………………………. 202

S-50 *Ksenija Janković, Dragan Bojović, Marko Stojanović, Iva Despotović, Ljiljana Lončar* - CONCRETE PAVING BLOCKS AND FLAGS MADE WITH RECYCLED AGGREGATE FROM PRECAST ELEMENTSTHE… 212

S-51 *Nikola Tošić, Snežana Marinković, Jorge de Brito, Nenad Pecić, Ivan Ignjatović* - LONG-TERM PROPERTIES OF GREEN CONCRETE: TESTING AT THE MATERIAL AND STRUCTURAL LEVEL………….... 218

S-52 *Dubravka Bjegović, Nina Štirmer, Ana Baričević* - CONCRETE USED IN LNG STORAGE TANKS…………………………………………………. 228

S-53 *Ksenija Janković, Marko Stojanović, Dragan Bojović, Ljiljana Lončar* - THE INFLUENCE OF POLYPROPYLENE FIBERS ON THE MECHANICAL PROPERTIES OF SHOTCRETE FOR SLOPES…………. 237

S-54 *Dragan Nikolić, Snežana Mitrović, Goran Ćirović* - ESTIMATION STRENGTH PROPERTIES OF UHPC……………………………………… 245

S-55 *Bojan Milošević, Slobodan Ranković, Žarko Petrović, Marina Mijalković* - OVERVIEW OF EXPERIMENTAL EXAMINATION OF LINEAR GIRDERS MADE OF SELF-COMPACTING CONCRETE………………... 255

S-56 *Aleksandar Savić, Marina Aškrabić, Brankica Kovačević, Danijela Pavlović* - PROPERTIES OF SCC MIXTURES WITH COARSE RECYCLED AGGREGATES…………………………………………………………… 265

S-57 *Živko P. Cuckić, Vesna Ž. Cuckić, Olga Cuckić* - AUTONOMOUS LOAD-BEARING FRAMEWORK TECHNOLOGY………………………………. 275

S-58 *Mirjana Malešev, Slobodan Šupić, Vlastimir Radonjanin, Mirjana Laban, Miroslava Radeka* - ECO BUILD - SUSTAINABLE USE OF WASTE MATERIALS FROM BIOMASS COMBUSTION…………………………. 282

S-59 *Žarko Lazić, Lev Zaretsky, Gordana Broćeta, Marina Latinović* - HIGH BOND 10-WIRE STRAND………………………………………………….. 290

S-60 *Aleksandar Radević, Jelena Dragaš, Vedran Carević, Dimitrije Zakić, Mladen Mladenović* - THE INFLUENCE OF DIFFERENT CURING CONDITIONS ON CEMENT AND HIGH VOLUME FLY ASH CONCRETE PROPERTIES………………………………………………. 300

S-61 *Franc Sinur, Aljoša Šajna, Teja Török Resnik, Jakob Šušteršič* - CONCRETE CONTAINER FOR DISPOSAL OF LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE……………………… 310

S-62 *Zlatko Zafirovski, Milorad Jovanovski, Vasko Gacevski* - TECHNICAL MEASURES FOR THE REHABILITATION IN THE HYDROTECHNICAL TUNNEL ON SASKA RIVER – M. KAMENICA… 319

S-63 *Liljana Dimevska, Meri Cvetkovska, Ana Trombeva Gavriloska, Marijana Lazarevska* - RESIDENTIAL BUILDINGS ANALYSIS ACCORDING TO THEIR ARHITECTURAL AND THERMAL CHARACTERISTICS……… 327

S-64 *Marija Docevska, Leart Taravari, Jose Campos e Matos, Goran Markovski* - QUALITY CONTROL PLAN OF ARCH CONCRETE BRIDGES………... 339

S-65 *Srđan Živković, Marko Milošević* - DIAGNOSTICS OF THE STATE OF STEEL BRIDGE OVER MLAVA RIVER………………………………….. 350

S-66 *Slobodan Cvetković, Ninoslav Milenković* - HERMANOS PATINO BRIDGE IN SANTIAGO DE LOS CABALLEROS – BRIDGE REHABILITATION………………………………………………………. 360

S-67 *Vlastimir Radonjanin, Mirjana Malešev, Ivan Lukić, Slobodan Šupić, Vesna Bulatović, Olivera Bukvić* - ASSESSMENT OF RC STRUCTURE OF PART OF THE "TV-CENTER" RTV ON MISELUK IN NOVI SAD…… 369

S-68 *Miloš Knežević, Ivana Tešović, Duško Lučić, Zlatko Zafirovski, Mladen Muhadinović* - REHABILITATION OF THE RAILWAY TRACK VIRPAZAR-BAR, IN THE TUNNEL “SOZINA“ IN MONTENEGRO…... 379

S-69 *Doncho Partov, Petar Grekov, Vesselin Kantchev* - SURVEY OF THE BURIED REINFORCED CONCRETE ARCH BRIDGE AND ITS APPLICATION IN BULGARIA……………………................................... 389

S-70 *Dunja Radovanović, Nenad Fric* - HOT-DIP GALVANIZING OF STEEL STRUCTURES – POSSIBILITIES AND LIMITATIONS………………….. 401

S-71 *Dunja Radovanović, Nenad Fric* - STEEL STRUCTURE CORROSION PROTECTION SYSTEMS ACCORDING TO THE EN ISO 12944 STANDARDS……………………………... 410

S-72 *Nikola Tošić, Andrija Radović, Bogdan Šakić, Snežana Marinković* - LONG-TERM DEFLECTIONS OF GREEN CONCRETE BEAMS: ANALYTICAL AND NUMERICAL CALCULATIONS…………………... 420

S-73	*Slobodan Ranković, Bojan Milošević, Žarko Petrović, Marina Mijalković* - TESTING OF HOLLOWED PRESTRESSED ELEMENTS FOR FLOOR SLABS…………………………………………………………………..	430
S-74	*Anka Starčev-Ćurčin, Andrija Rašeta, Mirjana Malešev, Danijel Kukaras, Đorđe Lađinović, Miloš Šešlija* - STRENGTH ASSESSMENT OF THE REINFORCED CONCRETE WALL DESIGNED BY STRUT-AND-TIE METHOD…………………………………………………………………..	438
S-75	*Svetlana Kostić, Biljana Deretić-Stojanović* - TWO NUMERICAL MODELS FOR NONLINEAR ANALYSIS OF CFT COULUMNS………...	446
S-76	*Nikola Ivanović, Jelena Dobrić, Milan Spremić, Nina Gluhović, Jovana Milovanović* - NON-LINEAR LATERAL BUCKLING ANALYSIS OF ALUMINIUM ALLOY CHANNEL BEAMS………………………………..	456
S-77	*Todor Vacev, Miloš Milić, Stepa Paunović, Ivan Nešović, Andrija Zorić* - APPLICATION OF NONLINEAR FEA ON LAMINATE STRUCTURES IN CASE OF A WATER TANK V=100 m^3……………………................	465
S-78	*Koce Todorov, Ljupčo Lazarov* - STRENGTH, STIFFNESS AND DUCTILITY OF MASONRY INFILLED FRAMES UNDER LATERAL LOADS……………………………………….....................................	475
S-79	*Stefan Kondić, Jelena Dobrić, Nina Gluhović* - DESIGN OF PEDESTRIAN BRIDGE ACCORDING TO EUROCODE 9……………………………...	485
S-80	*Fidan Salihu, Meri Cvetkovska, Ana Trombeva Gavriloska, Milivoje Milanović* - COMPARATIVE ANALYSIS ON FIRE RESISTANCE OF ONE WAY CONTINUOUS RC SLABS ACCORDING TO EC2 AND FEM…………………………………………………………………...	496
S-81	*Jagoda Kruškonja, Jelena Dobrić, Nina Gluhović* - RESISTANCE AND SERVICEABILITY ANALYSIS OF STEEL FOOTBRIDGE STRUCTURE ACCORDING TO EUROCODE………..	506
S-82	*Marina Rakočević* - AN INFLUENCE OF THE NUMBER OF LAYERS AND THE THICKNESS OF PLATE ON STRESS-STRAIN STATE IN A LAYERWISE PLATE THEORY…………………………………………….	516
S-83	*Ana Trombeva-Gavriloska, Marijana Lazarevska, Meri Cvetkovska, Miloš Knežević* - BOND STRESS DISTRIBUTION ALONG CFRP STRENGTHENED RC BEAM………………………………………………	522
S-84	*Igor Gjorgjiev, Marija Vitanova* - DAMPING IDENTIFICATION FOR NEW HIGHWAY BRIDGES TESTED UNDER DYNAMIC LOADING….	530

S-85	*Igor Gjorgjiev, Borjan Petreski, Vlado Micov* - EXPERIMENTAL STUDY OF BEAM-TO-COLUMN CONNECTION FOR PREFABRICATED RC STRUCTURE………………………………………………………….......	541
S-86	*Ilda Kovačević, Sanin Džidić* - POSSIBILITIES FOR PRODUCTION OF HIGH-STRENGTH CONCRETE (HSC) IN BOSNIA AND HERZEGOVINA………………………………………………………………..	549
S-87	*Marija Todorović, Boško Stevanović, Ivan Glišović, Tijana Stevanović* - END-NOTCHED GLULAM BEAMS REINFORCED WITH SCREWS…...	563
S-88	*Dragan Manojlović, Tatjana Kočetov Mišulić, Aleksandra Radujković* - WEIGHTED RESIDUAL METHOD IN ANALYSIS OF TIMBER CONCRETE COMPOSITE SYSTEM…………………................................	573
S-89	*Vladimir Živaljević, Mitar Đogo, Dušan Kovačević* - FEM ANALYSIS OF THE DYNAMIC TEST BY LOAD OF THE PILE………………..................	583
S-90	*Doncho Partov, V. K. Kantchev, Ch. P. Stoyanov* - ANALYSIS OF THE RELAXATION OF A BENDING MOMENT OVER THE SUPPORT IN A CONTINUOUS COMPOSITE BEAM USING INTEGRAL EQUATIONS OF VOLTERRA…………………………………………………………...	593
S-91	*Isidora Jakovljević, Saša Kovačević, Nenad Marković* - BUCKLING OF PLATES AND PLATE GIRDERS SUBJECTED TO PATCH LOAD……...	608
S-92	*Isidora Jakovljević, Zlatko Marković, Jelena Dobrić* - NUMERICAL EVALUATION OF FLEXURAL BUCKING OF HOT-FINISHED AND COLD-FORMED EHS COLUMNS………...	618
S-93	*Nina Gluhović, Milan Spremić, Zlatko Marković* - RECENT RESEARCH ON DUCTILITY OF PERFORATED SHEAR CONNCTORS……………..	627
S-94	*Aljoša Filipović, Jelena Dobrić, Zlatko Marković, Dragan Buđevac, Nenad Fric* - EXPERIMENTAL INVESTIGATION OF COMPRESSED STAINLESS STEEL ANGLE COLUMNS………………………………..	635
S-95	*Vlastimir Radonjanin, Mirjana Laban, Mirjana Malešev, Slobodan Šupić* - IMPROVING WESTERN BALKANS' RESILIENCE TO HAZARDS BY BUILDING CAPACITY IN HIGHER EDUCATION……………………….	645
S-96	*Ranko Babić, Lidija Babić, Radomir Folić* - NEW DESIGN OF TUNNEL HOODS FOR HIGH SPEED TRAINS……………………………………….	655
S-97	*Predrag Popović* - LESSONS LEARNED FROM MAJOR BRIDGE COLLAPSES…………………………………………………………………	664

ДГКС Друштво грађевинских конструктера Србије
ASES Association of Structural Engineers of Serbia
S-62
15. KONGRES
6-8. 9. 2018. Zlatibor

Zlatko Zafirovski[1], *Milorad Jovanovski*[2], *Vasko Gacevski*[3]

TEHNIČKE MERE ZA REHABILITACIJU U HIDROTEHNIČKOM TUNELU NA SASKA RIJECI – M. KAMENICA

Rezime:

Hidrotehnički tuneli predstavljaju izazovne konstrukcije sa stanovišta dizajna, izgradnje i održavanja. Obično su pod konstantnim dejstvom vode, zbog čega su skloni popravljanju i sanaciji. Funkcionalnost ovih vrsta tunela zavisi od odgovarajućih tehničkih mera koje su preduzete u njihovom ekspolatacionom periodu. Ovo uključuje znanje i stručnjake iz nekoliko naučnih oblasti. U ovom radu su prikazane neke od tehničkih mera za rehabilitaciju hidrotehničkog tunela na reci Sasa.

Key words: Hidrotehnički tunel; Analiza; Rehabilitacija; PLAXIS 3D

TECHNICAL MEASURES FOR THE REHABILITATION IN THE HYDROTECHNICAL TUNNEL ON SASKA RIVER – M. KAMENICA

Hydrotechnical tunnels represent challenging constructions from a design, construction and maintenance point of view. They are usually under constant effect of the water, which makes them prone to repairs and rehabilitation. The functionality of these kind of tunnels depends on the proper technical measures taken in their service period. This involves knowledge and experts from a few scientific areas. In this paper some of the technical measures for the rehabilitation of the hydrotechnical tunnel on Saska River are shown.

Key words: Hydrotechnical tunnel; Analysis; Rehabilitation; PLAXIS 3D

---

[1] PhD, Civ. Eng., Assistant Professor, University „Ss. Cyril and Methodius“, Faculty of Civil Engineering – Skopje, zafirovski@gf.ukim.edu.mk
[2] PhD, Geo. Eng., Professor, University „Ss. Cyril and Methodius“, Faculty of Civil Engineering – Skopje, jovanovski@gf.ukim.edu.mk
[3] B.Sc., Civ. Eng., Teaching Associate, University „Ss. Cyril and Methodius“, Faculty of Civil Engineering – Skopje, vaskogacevski@yahoo.com

1. INTRODUCTION

This tunnel is part of the mine for lead and zinc Sasa, which in one of the biggest and most famous mines in Macedonia, located in the eastern part of the country (Figure 1). It is approximately 12 km from the town Makedonska Kamenica at elevation of 1000 m.

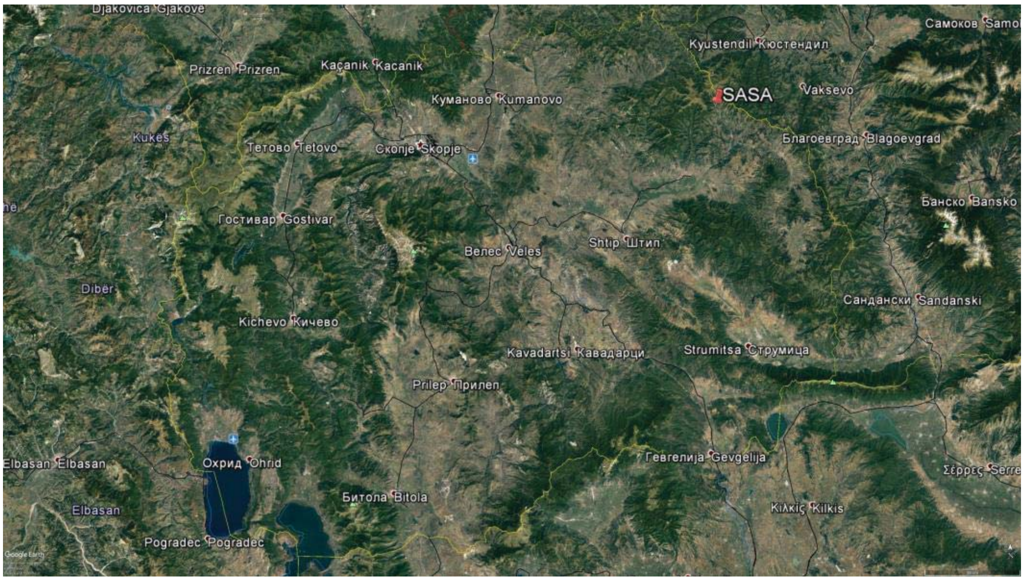

Figure 1 - Satellite view of the mine location (source: Google Earth)

1.1. GENERAL INFORMATION

The tunnel on Saska River is in function since 1971. It has a length of 1925 m with longitudinal slope of 5-7 %. The cross section varies in height and width (≈ 3 m) based on the geological composition and the support lining. Along the tunnel at a certain part are the tailings of the mine. The tailing are used for the disposal of the flotation pulp gained from the technological process of flotation of the minerals of lead and zinc. In the past three tailings have been realized, and another one is planned for the future exploitation period of the mine.

1.2. PREVIOUS REHABILITATIONS

There are several previous interventions made to this tunnel, that include: rehabilitation of the damaged concrete support lining, increasing durability and anti-corrosive protection of the concrete, injection of cracks and holes in the concrete and in the area between the rock and the concrete support, rehabilitation of the dilatation and the working joints, rehabilitation and protection of the invert arch, placement of additional shotcrete and rock bolts etc.

2. GEOLOGICAL AND GEOTEHNICAL PROPERTIES OF THE TERRAIN IN THE ZONE OF THE TUNNEL

The information for the geological condition of the terrain in the zone of the tunnel are collected from a few investigation stages, from which an appropriate base of geotechnical data was created.

2.1. LITHOLOGY

Present in the zone of the tunnel are the following natural and artificial compositions:

- Natural materials: gneiss rock, diluvial, proluvial and scree materials and alluvium (sandy gravel);
- Artificial materials: tailings sand (floatation pulp) and concrete from the tunnel support lining.

2.2. TECTONIC PROPERTIES

The character of the river valley and the condition and interaction of the represented rock masses indicate an intensive tectonic activity of this terrain in the geological past. The results from the investigations from which the faults and the fault zones where verified, also prove the complex tectonic condition of the terrain. The wider region belongs to zones with intensity of I = VIII° MCS (Mercali-Cancani-Sieberg). According to the national seismogenic sources the closest located area (berovsko-pehcevsko) is with expected intensity of I = XI° MCS, and expected magnitude of M = 7,5°.

2.3. ENGINEERING – GEOLOGICAL TYPES OF ROCK MASSES

There are two groups in which the represented rock masses in the zone of the tunnel can be divided:

- Strongly tied rock masses – represented by the gneisses which build the base of the terrain;
- Loose rock masses – represented by the alluvial sediments and the floatation pulp.

2.4. HYDROGEOLOGICAL PROPERTIES

The represented rock masses according to their hydrogeological function in the terrain assembly behave as collectors and isolators.

In the group of hydrogeological collectors belong the alluvial sediments and the flotation pulp (tailings).

In the group of hydrogeological isolators belong the strongly tied rock masses (gneisses).

2.5. GEOTECHNICAL CHARACTERISTICS OF THE ROCK MASSES

Most of the information's for the characteristics of the rock masses where obtained from the existing technical documentation.

- Gneisses: RQD=30 %, σ_p=30 MPa, c=300 KPa, φ=36°, γ=25 kN/m^3, ν=0.30, RMR= III class;

- Gravel: E=52000 kN/m^2, ν=0.28, c=0 KPa, φ=34°, γ=22.18 – 22.80 kN/m^3;
- Flotation pulp: c=0 KPa, φ=31°, γ=18 – 20.5 kN/m^3.

Figure 2 – Tunnel exit

3. CURRENT STATE OF THE TUNNEL

From the completely made analysis, the on-site inspection in the tunnel, and the overall results it has been noted that the hydrotechnical tunnel on Saska River can adequately perform its function.

However, due to the observed irregularities along the tunnel in terms of established and identified defects, it was recommended to apply measures with which the functionality of the tunnel construction would increase, and this would result in better condition and longer exploitation period for using the tunnel.

Mostly the irregularities refer to increased amount of water on the walls of the tunnel and some damages to the support lining. A specific defect which is present along the tunnel is the damage of the concrete invert. Along the length of the tunnel almost the entire bottom where the water flows is eroded and is some places a channel with a depth of over 20 cm was formed.

4. REHABILITATION SOLUTIONS AND ANALYSIS OF THE TUNNEL

The tunnel is divided in few sections:

- Parts with primary (rock bolts and reinforced shotcrete) and secondary support (reinforced concrete lining);
- Parts with only primary support (rock bolts and reinforced shotcrete);
- Parts with no support (only rock mass).

The rehabilitations solutions vary depending on the sections.

4.1. REHABILITATION OF THE TUNNEL SECTIONS WITH ONLY PRIMARY SUPPORT

Parts of the tunnel have only primary support (reinforce shotcrete d=20 cm and rock bolts La=2,5 m ap/an=1,25/1,25 m) and invert arch with no secondary support. For these segments multiple variant solutions where considered:

- Solution 1: Partial secondary support – pillars (reinforced concrete d=30 cm);
- Solution 2: Full secondary support above the invert (reinforced concrete d=30 cm);
- Solution 3: Rehabilitation of the invert with anchors, new reinforcement and new layer of concrete (d=20 cm).

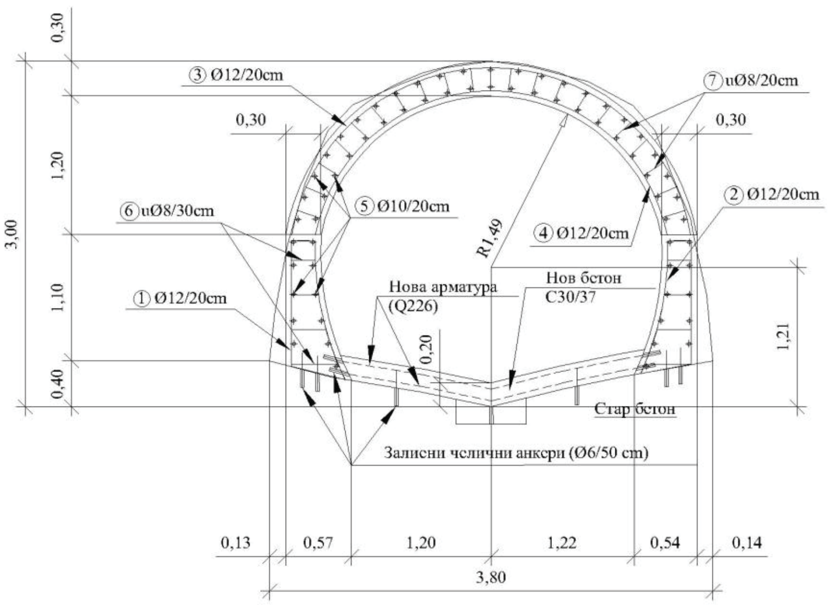

Figure 3 – Tunnel cross section with full secondary support

4.2. ANALYSIS OF THE TUNNEL SECTIONS WITH ONLY PRIMARY SUPPORT

The analysis was made for multiple variant solutions covering several stages:

- Solution 1: Analysis of the tunnel with the invert from reinforced concrete and primary support from reinforced shotcrete and rock bolts (for stability control);
- Solution 2: Analysis of the tunnel with the invert and pillars from reinforced concrete, as well as primary support from reinforced shotcrete and rock bolts;
- Solution 3: Analysis of the tunnel with primary and full secondary support (d=30 cm);
- Solution 4: Analysis of the tunnel with primary and secondary support, without the invert.

The analysis process was simulated in the numerical model in multiple phases:

- Phase 1: Initial stress condition in the massif before construction;
- Phase 2: Excavation of the tunnel and construction of the invert with the pillars;
- Phase 3: Pseudo-static analysis.

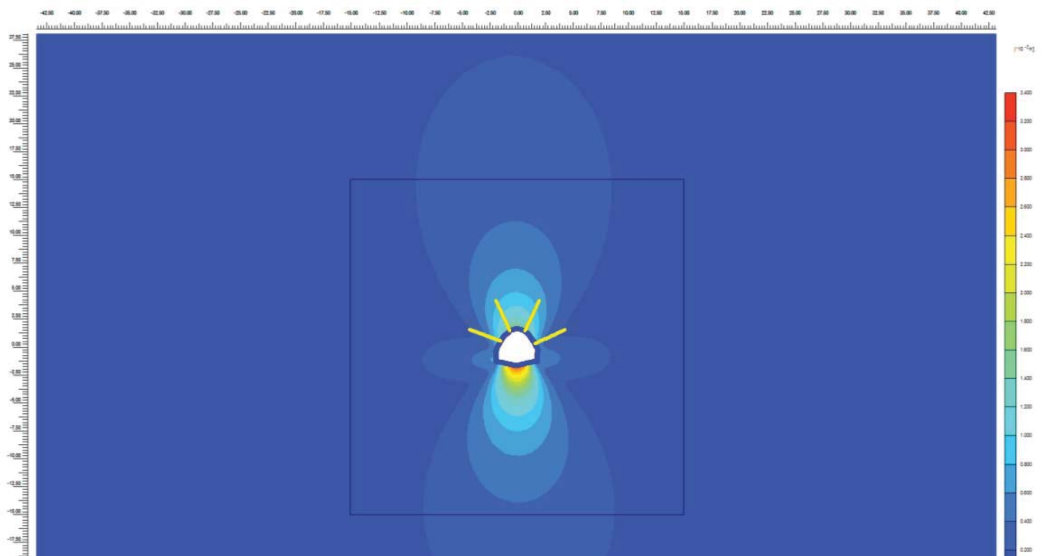

Figure 4 – Deformations of the local environment and the lining

The maximum deformations in the local environment are 3.24 mm. The results from the analysis show that the bigger static values occur in seismic conditions.

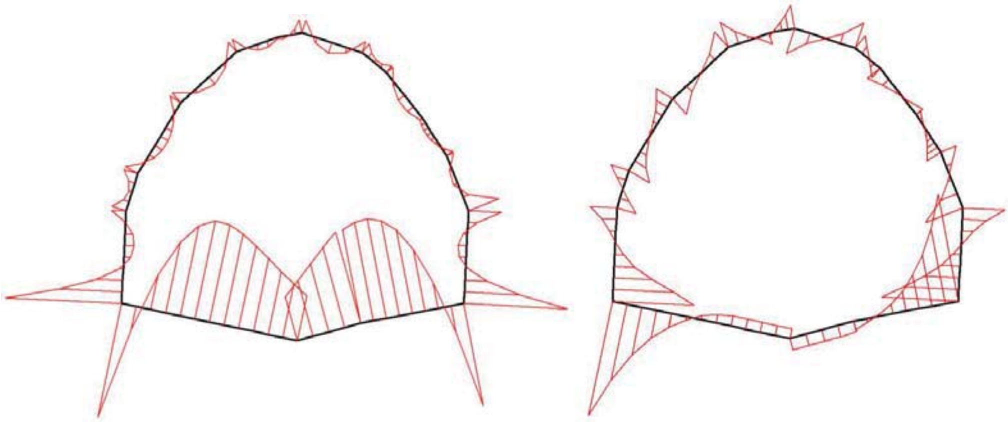

Figure 5 – Diagrams of bending moment (left) and transversal forces (right)

5. CONCLUSIONS

For proper exploitation and long lasting service life, the rehabilitation and maintenance is mandatory process for hydrotechnical tunnels. The rehabilitation solutions and analysis for the tunnel on Saska River shown in this paper are just part of the complexed process that enables the improvement of the tunnel construction bearing capacity and functionality. This process requires qualified experts from different scientific areas and adequate detailed information's regarding the local environment, previous conditions, rehabilitations and interventions and the current state of the tunnel.

REFERENCES

[1] Construction design of the "Saska" river diversion tunnel, stage II, Faculty of Civil Engineering, Skopje, 2006.

[2] Design of rehabilitation of the lining of the "Saska" river diversion tunnel from survey mark 1+200 to survey mark 1+717 and rehabilitation of the invert, Faculty of Civil Engineering, Skopje, 2003.

[3] As built design of the "Saska" river diversion tunnel (stage II), Faculty of Civil Engineering, Skopje, 2008.

[4] As built design of the injection works at the "Saska" river diversion tunnel, stage II, Geofluid, Skopje, 2007.

[5] Geodetic report on the surveys conducted for special purposes, Geomer, Delcevo, 2009.

[6] Partial – technical solution for the accompanying facility of the diversion collector "Velkovski stream" */shaft – diversion tunnel/* after raising the "New TSF" of Sasa mine – M. Kamenica – stage I, above elevation 990.0 m, Mine institute "Zavod PMS", Skopje, 2000.

[7] Construction report on completed activities aimed at rehabilitation of the damaged sections of collector no. 6 between survey marks 0+90 and 0+120 at the lead and zinc mine “Sasa” – M. Kamenica, RE-KO Inzenering, 2007.

[8] Main design on rehabilitation of a section of the “Saska” river diversion tunnel at survey mark 0+970 – 1+140.5, Civil Engineering institute “Makedonija”, Skopje, 2005.

[9] Addenda to the main design on rehabilitation of a section of the “Saska” river diversion tunnel at survey mark 0+960 – 1+140.5 Civil Engineering institute “Makedonija”, Skopje, 2006.

[10] Technical solution for rehabilitation of the “Saska” river diversion tunnel at survey mark 1+150 – 1+200 km./, beneath the new tsf of Sasa mine – M. Kamenica – stage I, Mining institute – Department for mineral processing, Skopje, 2002.

[11] Technical solution for rehabilitation of the “Saska” river diversion tunnel at survey mark 1+150 – 1+200 km. /tunnel type - v./ beneath the new tsf of Sasa mine – M. Kamenica – stage I, Mining institute – Department for mineral processing, Skopje, 2002.

[12] Main design for rehabilitation of the invert of “Saska” river diversion tunnel from km. 0+000 to km. 0+950, Faculty of Civil Engineering, Skopje, 2010.