

CONFERENCE
PROCEEDINGS

**3RD INTERNATIONAL
ACADEMIC CONFERENCE ON
PLACES AND TECHNOLOGIES**

EDITORS
EVA VANIŠTA LAZAREVIĆ
MILENA VUKMIROVIĆ
ALEKSANDRA KRSTIĆ-FURUNDŽIĆ
AND ALEKSANDRA ĐUKIĆ

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Eva VaništaLazarević, Milena Vukmirović, Aleksandra Krstić-Furundžić, Aleksandra Đukić

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PLACES AND TECHNOLOGIES 2016

KEEPING UP WITH TECHNOLOGIES TO CREATE COGNITIVE CITY
BY HIGHLIGHTING ITS SAFETY, SUSTAINABILITY, EFFICIENCY,
IMAGEABILITY AND LIVEABILITY

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TABLE OF CONTENTS

ARCHITECTURAL TECHNOLOGIES I – ENERGY ISSUES

DETERMINATION OF ENERGY CHARACTERISTICS OF TRANSPARENT ELEMENTS OF ENVELOPE OF RESIDENTIAL BUILDINGS IN BOSNIA AND HERZEGOVINA Darija Gajić	3
ECO-ENERGETIC RECONSTRUCTION OF ARCHITECTURAL STRUCTURES BY APPLYING MODERN FACADE TECHNOLOGIES Olja Joksimović, Katarina Vukosavljević	11
MODERNIZATION OF EXISTING GLASS FACADES IN ORDER TO IMPLEMENT ENERGY EFFICIENCY AND MEDIA CONTENT Jasna Čikić Tovarović, Jelena Ivanović Šekularac, Nenad Šekularac	19
EFFECTS OF WINDOW REPLACEMENT ON ENERGY RENOVATION OF RESIDENTIAL BUILDINGS – CASE OF THE SERBIAN BUILDING PRACTICE Ana Radivojević, Aleksandar Rajčić, Ljiljana Đukanović	27
GREEN ROOF RETROFIT POTENTIAL IN A DENSELY POPULATED BELGRADE MUNICIPALITY Katarina Vukosavljević, Olja Joksimović, Stevan Vukadinović	35
ENERGY REFURBISHMENT OF PUBLIC BUILDINGS IN SERBIA Milica Jovanović Popović, Miloš Nedić, Ljiljana Djukanović	43
PROBLEM OF PROTECTION OF ORIGINAL APPEARANCE OF PREFABRICATED CONCRETE FACADES AND ENERGY IMPROVEMENT MEASURES – EXAMPLE OF NEW BELGRADE Nikola Macut, Ana Radivojević	51
SUNLIGHTING: A BRIGHT LIGHT SOURCE FOR MULTI-STORY BUILDING CORES Liliana Beltran	59

ARCHITECTURAL TECHNOLOGIES II - INNOVATIVE METHODS, SOFTWARE AND TOOLS

BIM AND GREEN BUILDING DESIGN: EXPECTATIONS, REALITY AND PERSPECTIVES Igor Svetel, Marko Jarić, Nikola Budimir	69
UNDER THE SKIN - DETERMINING ELECTRICAL APPLIANCES FROM SURFACE 3D SCANS Ulrich Krispel, Torsten Ullrich, Martin Tamke	77
ARCHITECTURAL DIAGRAM OF A CITY Olivera Dulić, Viktorija Aladžić	85
DIGITAL TOOLS - BASED PERFORMANCE EVALUATION OF THE ADAPTIVE BUILDING ENVELOPE IN THE EARLY PHASE OF DESIGN Komnen Žižić, Aleksandra Krstić-Furundžić	93

INCREASING QUALITY OF PLACE BY USERS VALUE ORIENTATION Alenka Temeljotov Salaj, Svein Bjorberg, Nikolaj Salaj	101
COMFORT QUALITY IN THE ARCHITECTURAL TRANSFORMATION OF EXISTING FACILITIES Saša B. Čvoro, Malina B. Čvoro, Una Umićević	109
BUILDING STRUCTURES AND MATERIALS	
CONCEPTUAL STRUCTURAL DESIGN STRATEGIES FOR REDUCING ENERGY CONSUMPTION IN BUILDINGS Aleksandra Nenadović, Žikica Tekić	119
COMPARISON OF THE SUSTAINABILITY OF DIFFERENT TECHNIQUES FOR THE STRENGTHENING OF REINFORCED CONCRETE COLUMNS Tanya Chardakova, Marina Traykova	125
THE ARCHITECTURAL ASPECT OF DESIGNING THE OFFICE ENVIRONMENT IN THE MULTIFUNCTIONAL BUILDING IN THE CITY CENTRE Anna Rynkowska-Sachse	133
MITIGATE THE HOUSING DEPRIVATION IN THE INFORMAL CITIES: MODULAR, FLEXIBLE AND PREFAB HOUSES Frabrizio Finucci, Adolfo Barrata, Laura Calcagnini, Antonio Magaro, Ottavio Minnella, Juan Martin Piaggio	141
AN EXAMPLE OF USING RECYCLED CRUSHED CLAY BRICK AGGREGATE: A PREFABRICATED COMPOSITE FAÇADE PANEL WITH THE FACE OF STONE Tijana Vojinović Čalić, Dragica Jevtić, Aleksandra Krstić-Furundžić	149
CLIMATE CHANGE I – ENERGY ISSUES	
ENERGY MAP OF KRAGUJEVAC AS AN INTRODUCTION TO THE ANALYSIS OF NECESSARY INTERVENTION MEASURES ON BUILDINGS IN ORDER TO ADAPT TO CLIMATE CHANGE Iva Poskurica Glišović	159
THE IMPACT OF CLIMATE CHANGE ON THE ENERGY PERFORMANCE OF HISTORICAL BUILDINGS Alexandra Keller, Cristian Petrus, Marius Mosoarca	167
INFLUENCE OF DIFFERENT PAVEMENT MATERIALS ON WARMING UP OF PEDESTRIAN AREAS IN SUMMER SEASON Jelena Đekić, Petar Đekić, Milena Dinić Branković, Mihailo Mitković	175
ANALYSIS OF ELECTRICITY GENERATION RESULTS OF FIRST MINI SOLAR POWER PLANTS IN THE SOUTH OF SERBIA WITH VARYING INCLINATION OF PHOTOVOLTAIC PANELS AND DIFFERENT ENVIRONMENTAL CONDITIONS Mihailo Mitković, Jelena Đekić, Petar Mitković, Milica Igić	183
EDUCATION NEEDS AND INFLUENTIAL FACTORS ON ENVIRONMENTAL PROTECTION IN FUNCTION OF SUSTAINABLE DEVELOPMENT AT HIGHER EDUCATION INSTITUTIONS Marijola Božović, Milan Mišić, Zorica Bogićević, Danijela Zubac	191

BUILDING CLIMATE CHANGE II – STRATEGIES, PROTECTION AND FLOODS

EVALUATING THE CO-BENEFITS OF FLOOD MITIGATION MEASURE – A CASE STUDY OF SOUTHERN YUNLIN COUNTY IN TAIWAN Yi-Hsuan Lin	201
FLOODING RISK ASSESSMENT IN MOUNTAIN VILLAGES—A CASE STUDY OF KAOHSIUNG CITY Ting-Chi Hsu, Han-Liang Lin	209
SPATIAL PLANNING IN VIEW OF FLOOD PROTECTION-METHODOLOGICAL FRAMEWORK FOR THE BALCAN COUNTRIES Brankica Milojević	217
CLIMATE WARS AND REFUGEES: HUMAN SECURITY AS A PATHWAY TOWARDS THE POLITICAL? Thomas Schad	225
LOW-IMPACT DEVELOPMENT STRATEGIES ASSESSMENT FOR URBAN DESIGN Yu-Shan Lin, Han-Liang Lin	235

SUSTAINABLE COMMUNITIES AND PARTICIPATION I – PLANNING ISSUES

THE POSSIBILITIES OF SURVEY AS A METHOD TO COLLECT AND THE DERIVE MICRO-URBAN DATA ABOUT NEW COLLECTIVE HOUSING IN SERBIA Branislav Antić	247
POSITION OF THE SOCIAL HOUSING ACCORDING TO THE URBAN PLANNING REGULATION OF THE CITY OF NIS – DO THEY PROMOTE THE INCLUSION? Nataša Petković Grozdanović, Branislava Stoiljkovic, Goran Jovanović	255
INFLUENCE OF DIFFERENT APPROACHES IN DEVELOPMENT OF LOCAL RESIDENTIAL BUILDING TYPOLOGIES FOR ESTIMATION OF BUILDING STOCK ENERGY PERFORMANCE Milica Jovanović Popović, Dušan Ignjatović, Bojana Stanković	263
TOWARDS A LOW-CARBON FUTURE? CONSTRUCTION OF DWELLINGS AND ITS IMMEDIATE INFRASTRUCTURE IN CITY OF SPLIT Višnja Kukoč	271
SCENARIOS IN URBAN PLANNING AND THE MULTI-CRITERIA METHOD. A MEANINGFUL EXPERIENCE IN ITALY: PIANO IDEA IMPLEMENTED IN JESI AN,2004 Giovanni Sergi, Paolo Rosasco	279
THE PUBLIC INSIGHT AND INCLUSIVITY IN THE PLANNING PROCESS Nataša Danilović Hristić, Nebojša Stefanović	287
TOWARD THE SUSTAINABLE CITY – COMMUNITY AND CITIZENS INCLUSION IN URBAN PLANNING AND DESIGN OF URBAN GREEN SPACES: A REVIEW OF SKOPJE Divna Penčić, Snezhana Domazetovska, Stefanka Hadji Pecova	295

SUSTAINABLE COMMUNITIES AND PARTICIPATION II – CONCEPTS, METHODS AND COMMUNITY

HOW TO DEVELOP AND DESIGN HEALTHY URBAN ENVIRONMENT? Sanja Štimac, Anja Jutraž	305
SUSTAINABILITY AND BROWNFIELD REGENERATION Kristina Azarić	313
THE SOCIAL DIMENSION OF A SUSTAINABLE COMMUNITY: UNDERSTANDING OF THE EXISTING SPACE Silvia Grion, Elisabeth Antonaglia, Barbara Chiarelli	319
HOW TO UNDERSTAND THE GLOBAL PHENOMENON OF URBAN SHRINKAGE AT LOCAL LEVEL? COMPARISON OF URBAN AREAS IN ROMANIA AND SERBIA Mihai-Ionut Danciu, Branislav Antonić, Smaranda Maria Bica	327
SPATIAL PATTERNS OF SERBIAN MIGRANTS IN VIENNA AND IN THE SETTLEMENTS OF THEIR ORIGIN IN EASTERN SERBIA Branislav Antonić, Tamara Brajović	335
KEEPING THE CITY LIVEABLE FOR INHABITANTS AND EFFICIENT FOR TOURISTS: THE PILGRIMAGE ROUTES Lucia Martincigh, Renata Bizzotto, Raffaella Seghetti, Marina Di Gauda, Giovanni Perrucci	347
ENVIRONMENTAL PROBLEMS AND CITIZEN PARTICIPATION IN MEDIUM-SIZED TOWNS OF SERBIA Anđelka Mirkov	355
URBAN PROBLEMS OF HILLY AND MOUNTAINOUS RURAL SETTLEMENTS IN NIŠ MUNICIPALITY Milica Igić, Petar Mitković, Jelena Đekić, Milena Dinić Branković	361

IMAGE, IDENTITY AND QUALITY OF PLACE I – PLANNING ISSUES

THE STRATEGIES OF PLACE-MAKING. SOME ASPECTS OF MANIFESTATIONS OF POSTMODERN IDEAS IN LITHUANIAN ARCHITECTURE Martynas Mankus	373
DESIGNING CENTERS OF SUBURBAN SETTLEMENTS IN THE POST-SOCIALIST CITY – NIŠ CASE STUDY Milena Dinić Branković, Jelena Đekić, Petar Mitković, Milica Igić	381
TRANSITION AND THE CITY: TRANSFORMATION OF URBAN STRUCTURE DURING THE POST-SOCIALIST PERIOD Dejana Nedučin, Milena Krklješ	389
POST INDUSTRIAL CITIES: CREATIVE PLAY - FAST FORWARD BELGRADE 2016 Eva Vaništa Lazarević, Marija Cvetković, Uroš Stojadinović	395
THE FUTURE OF OLD INDUSTRIAL AREAS - SUSTAINABLE APPROACH Anica Tufegdžić, Maria Siladji	405

CREATING IDENTITY AND CHARACTER OF NEW SETTLEMENT FORMED DUE TO GROWTH OF THE CITY- ON THE EXAMPLE OF PODGORICA Ema Alihodžić Jašarović, Edin Jašarović	413
SPINUT-POLJUD RESIDENTIAL AREA IN SPLIT, CROATIA Vesna Perković Jović	421
IMAGE, IDENTITY AND QUALITY OF ZAPRUĐE HOUSING DEVELOPMENT IN NOVI ZAGREB Ivan Milnar, Lea Petrović Krajnik, Damir Krajnik	429
URBAN IDENTITY OF BORDER SPACES. CONSTRUCTING A PLACE IN THE BORDER CROSSING BETWEEN SPAIN AND MOROCCO IN CEUTA Belen Bravo Rodriguez, Juan Luis Rivas Navarro, Alicia Jiménez Jiménez	435
ZEITGEIST & GENIUS LOCI: TRADE VALUE AESTHETIC AND WEAKNESS OF AUTHOR'S IDENTITY IN RECENT SERBIAN ARCHITECTURE Aleksandar Kadijević	445
 IMAGE, IDENTITY AND QUALITY OF PLACE II – PUBLIC SPACES	
PRESERVING PLACE MEANING IN FUNCTION OF TRANSFORMATION OF OPEN PUBLIC SPACES Ana Špirić, Sanja Trivić	455
STREET LIFE DIVERSITY AND PLANNING THE URBAN ENVIRONMENT. COMPARATIVE STUDY OF SOFIA AND MELBOURNE Silvia Chakarova	463
TRANSFORMATIONS AND PERMANENCE OF REPUBLIC SQUARE Stefan Škorić, Milena Krklješ, Dijana Brkljač, Aleksandra Milinković	473
THE IMAGE OF THE CITY VS. SEMI-PUBLIC SPACES OF SHOPPING MALLS: CASE STUDY OF BELGRADE Marija Cvetković, Eva Vaništa Lazarević	481
THE MARKET HALL OF PÉCS Balazs Kokas, Hutter Ákos, Veres Gábor, Engert Andrea, Greg András, Sike Ildikó, Alexandra Pető	489
INNOVATIVE PUBLIC SPACE REHABILITATION MODELS TO CREATE CONDITIONS FOR COGNITIVE - CULTURAL URBAN ECONOMY IN THE AGE OF MASS INDIVIDUALISATION Katarzyna Bartoszewicz, Piotr Lorens	497
ILLUMINATION OF FACADES OF PUBLIC BUILDINGS IN NOVI SAD AND ITS IMPACT ON SPATIAL PERCEPTION Dijana Brkljač, Milena Krklješ, Aleksandra Milinković, Stefan Škorić	507
COGNITIVE PERFORMANCES OF PEDESTRIAN SPACES Milena Vukmirović, Branislav Folić	515

IMAGE, IDENTITY AND QUALITY OF PLACE III – CONCEPT, METHODS, EDUCATION

THE CRIMINAL CITY: URBAN RESET AFTER "COLECTIV" Agelica Stan	527
TOWARD THE ULTIMATE SHAPE-SHIFTER: TESTING THE OMNIPOTENCE OF DIGITAL CITY Aleksandra Stupar, Tatjana Mrđenović	535
MANAGEMENT OF URBAN IMAGE AS A TOOL FOR PLANNING. THE CASE OF THESSALONIKI Kleoniki Gkioufi, Eleni Gavra	541
VISIBLE AND INVISIBLE PROCESSES AND FLOWS OF TIME-SPACE OF ARCHITECTURAL AND URBAN CONTINUITY OF THE CITY Velimir Stojanović	549
FORMS OF CONTINUITY IN ARCHITECTURAL SPACE Petar Cigić, Milena Kordić	555
URBAN DESIGN EDUCATION FOR PLACEMAKING: BETWEEN COGNITION AND EMOTION Jelena Živković, Zoran Đukanović, Uroš Radosavljević	565
SKETCHBOOK AS AN ARCHITECTURAL DESIGN INSTRUMENT OF THE COGNITIVE CREATION PROCESS FOR THE QUALITY OF PLACE Igor Rajković, Uroš Radosavljević, Ana Zorić	573
THE MUSICALITY OF UNDULATING GLASS PANES IN THE CONVENT OF LA TOURETTE Marko Slaviček, Anja Kostanjšak	581
THE ROUTES OF DIGITALIZATION – FROM REAL TO VIRTUAL CITY AND VICE VERSA Miodrag Ralević, Tatjana Mrđenović	587
RESILIENCE OF PLACES	
A SHRED OF PLACE IN A DIGITAL ERA HUMANITARIAN DISASTER Pavlos Lefas, Nora Lefa	599
URBAN SPACES MORPHOLOGY AND MICROCLIMATE CONDITIONS: A STUDY FOR A TYPICAL DISTRICT IN THESSALONIKI Stella Tsoka, Katerina Tsikaloudaki, Theodoros Theodosiou	605
SPONTANEOUS DEVELOPMENT AND RESILIENCE PLACES – A CASE STUDY OF ELECTRONIC INDUSTRY NIS (SERBIA) Liljana Jevremović, Branko Turnsek, Aleksandar Milojkovic, Milanka Vasic, Marina Jordanovic	613
SUSTAINABLE MODEL FOR REGIONAL HOSPITALS IN HUMID TROPICAL CLIMATE Nataša Čuković Ignjatović, Dušan Ignjatović, Dejan Vasović	621

MATERIAL AND COGNITIVE STRUCTURES OF BUILDINGS AND PLACES AS INTEGRATED PATTERNS OF PAST, PRESENT AND FUTURE Dženana Bijedić, Rada Cahtarevic, Mevludin Zecević, Senaida Halilović	627
BOOSTING THE RESILIENCE OF THE HEALTHCARE SYSTEM IN BELGRADE: THE ROLE OF ICT NETWORKS Jelena Marić, Aleksandra Stupar	635
INTERCONNECTION OF ARCHITECTURE AND NEUROSCIENCE - RESHAPING OUR BRAINS THROUGH PHYSICAL STRUCTURES Morana Pap, Mislav Pap, Mia Pap	645
THE POTENTIAL OF URBAN AGRICULTURE IN REVITALIZATION OF A METROPOLIS Gabriela Rembarz	651
 ADAPTIVE REUSE	
IMPROVING STRATEGIES FOR FUNCTIONAL UPGRADE FOR AN "INTEGRATED REHABILITATION" Francesca Guidolin	661
ADAPTIVE REUSE AND SOCIAL SUSTAINABILITY IN THE REGENERATION PROCESSES OF INDUSTRIAL HERITAGE SITES Sonja Ifko, Ana Martinović	669
REVEALING THE MONTENEGRIN KATUN AS A PLACE OF REUSABLE COGNITIVE TECHNOLOGIES Edin Jašarović, Ema Alihodžić Jašarović	683
INTERSECTIONS OF NOW AND THEN; IMPLEMENTATION OF ADAPTIVE REUSE AS CATALYST OF SPACE TRANSFORMATION Anja Kostanjšak, Nikola Filipovic	691
MULTIFAMILY HOUSING IN BELGRADE – ENERGY PERFORMANCE IMPROVING POTENTIAL AND ARCHITECTURAL CHALLENGES Nataša Ćuković Ignjatović, Dusan Ignjatovic, Bojana Stankovic	699
SPATIAL STRUCTURE OF THE SUBURBAN ZONES IN SELECTED ENTREPRENEURSHIPS NESTS OF THE TRICITY METROPOLITAN AREA Grzegorz Pęczek, Justyna Martyniuk-Pęczek	707
 INNOVATIVE METHODS AND APPLICATIONS FOR SMART(ER) CITIES	
TECHNOLOGY AS A MEDIATOR BETWEEN MAN AND CITY IN THE CONTEXT OF CONTEMPORARY CHALLENGES Katarina Stojanović	725
CITY INTELLIGENCE INFORMATION MODELING Alice Pasquinelli, Silvia Mastrolembro, Franco Guzzeti, Angelo Ciribini	731
AN INTRODUCTION TO THE PHYSICAL PLANNING INFORMATION SYSTEM OF CROATIA AND NEW GENERATION OF SPATIAL PLANS Sunčana Habrun, Lidija Škec, Danijel Meštrić	739

THE CONCEPT OF SMART ARCHITECTURE IN SERBIA – ONE BELGRADE EXPERIENCE Dragan Marčetić, Andrej Josifovski	747
THE IDEA OF COGNITIVE CITY - A CHALLENGE FOR NEW TECHNOLOGY TO PROMOTE HEALTH Aleksandra Krstić Furundžić, Nikola Z. Furundzić, Dijana P. Furundzić	755
MIXED REALITY ENVIRONMENT AND OPEN PUBLIC SPACE DESIGN Aleksandra Đukić, Dubravko Aleksić	761
VULNERABILITY OF PUBLIC SPACE AND THE ROLE OF SOCIAL NETWORKS IN THE CRISIS Milena Vukmirović, Miroslava Raspopović	769
NEUTRAL GROUNDING POINTS WITHIN THE GENERAL DISTRIBUTION SYSTEM AS AN ELEMENT OF ENVIRONMENTAL PROTECTION Zorica Bogičević, Slobodan Bjelić, Bojan Jovanović, Milan Misic	779
THE ROLE OF COGNITIVE – CULTURAL ECONOMY IN CITY’S GLOBAL POSITIONING Sanja Simeunčević Radulović, Biserka Mitrović	789
URBAN MOBILITY, TRANSPORT AND TRAFFIC SOLUTIONS	
THE CONTRIBUTION OF ITS TO THE SAFETY IMPROVEMENT OF VULNERABLE ROAD USERS Bia Mandžuka, Ljupko Šimunović, Pero Škorput	799
BUILDING ENVIRONMENTAL PERSPECTIVE OF AIRCRAFT OPERATIONS AROUND BELGRADE NIKOLA TESLA AIRPORT Olja Čokorilo, Ivana Čavka	805
TRANSPORT PROJECTS AND PUBLIC PARTICIPATION Davor Brčić, Stjepan Kelcec-Suhovec	813
DISLOCATION OF THE EXISTING RAILWAY AND BUS STATION IN THE CITY OF KUMANOVO AND THEIR INTEGRATION INTO A TRANSPORT HUB WITH ADJOINING CONTENTS Mihajlo Zinoski, Medarski Igor, Stefani Solarska	817
THE IMPACTS OF TRANSPORT INFRASTRUCTURES ON URBAN GEOGRAPHY Federico Andrea Innarone	825
LIQUID LIFE: A RELATIONSHIP BETWEEN VULNERABILITY AND MOBILITY – THE CONSEQUENCES FOR A SUSTAINABLE CITY, StevanTatalović	831

AN EXAMPLE OF USING RECYCLED CRUSHED CLAY BRICK AGGREGATE: A PREFABRICATED COMPOSITE FAÇADE PANEL WITH THE FACE OF STONE

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ABSTRACT

The contemporary trend of sustainability and waste management, among other principles of environmental preservation, promote recycling of building waste material. Building waste material may contain significant quantities of discarded bricks and concrete, which can be further used crushed, as aggregate. In line with the principle of recycling, the following research displays a possibility of using recycled crushed clay brick aggregate to form a prefabricated composite façade panel with a face of stone, which can be used within a ventilated façade system. The paper presents the production technology of a pilot element and design possibilities of the panel. The research contributes to the environmental preservation and sustainability concept by offering an example of using recycled building waste within a new building element.

Keywords: prefabrication, recycling of building waste, crushed clay brick aggregate, façade panel

INTRODUCTION

Sustainable development is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, n.d.). In the context of sustainability, it is desirable that the whole life cycle of a building has as little as possible damaging impact on the environment. In line with aforementioned, the *4R* approach to waste management includes some of the key principles of sustainable development: *reduce*, *reuse*, *recycle* and *recover*. Recycling, addressed in this paper, involves melting or crushing of waste

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materials, extracting component materials in the form of raw materials, which can re-enter the production process. If it is not possible to apply either one of the aforementioned principles, waste *disposal* at a landfill is the option. That is the worst option in terms of the environmental protection (Jevtić, Zakić i Savić, 2009; Kareem and Pandey, 2013)

According to Kim and Rigdon (1998), sustainable design in architecture, which is to be observed during the entire life cycle of a building is, among other methods, based on reuse of building elements, use of recycled materials and materials that are recyclable. The advantage of reuse and recycling is the conservation of energy which is embedded in building element - embodied energy², and would otherwise be lost. Reuse and recycling reduce the amount of waste material and the need for the landfill space which is scarce, as well as the consumption of new natural resources and the negative impact of their exploitation. Recycled aggregates from construction and demolition of buildings used at the building site contribute to reducing negative impacts of transport by reducing the emission of toxic gases (Kim and Rigdon, 1998).

The construction industry is a major consumer of natural resources and also a major producer of building construction and demolition waste (Cachim, 2009). Bricks and roof tiles could often be found as waste materials. If they cannot be cleaned and reused, recycled crushed aggregate can be profitably used for drainage, as a road base, concrete aggregate, etc. Reuse and recycling of brick products must be considered with care, as the consumption of energy during their production is relatively high. On the other hand, the consumption of energy needed to extract and clean used bricks could amount to only 0.5% of the energy needed for their production. These products could also be milled into pozzolanic powder and used as raw material (Berge, 2009).

Thanks to its wide application and composite nature, concrete is often perceived as suitable for the application of recycled aggregates, such as recycled bricks, tires, etc. Aggregate constitutes 60-80% of the total volume of concrete, and any reduction in natural aggregate consumption has a favourable effect on the environment (Cachim, 2009). Also, concrete could be further recycled and used as aggregate within a new cement composite mixture.

Constant efforts are being invested in research concerning the possibility of applying recycled waste in mortars and concretes, as well as within prefabricated elements as paving blocks (Poon and Chan, 2006), solid and hollow masonry blocks (Jevtić, Zakić, Markićević, Pavlović i Terzić, 2006), etc. The following paper presents a manufacturing technology and design options of a pilot element – a composite façade panel with the face of stone, which can be applied within a ventilated façade system.

CONSTITUENT MATERIALS

The proposed façade panel includes two distinct layers: a base and a face of stone. The base is composed of a lightweight aggregate fibre-reinforced cement composite (mortar) with the thickness of 2.5 cm. The face consists of stone tile mosaic with the thickness of 1.0 cm. The overall thickness of the pilot element with the designed area of 60 x 60 cm is 3.5 cm.

Portland-composite cement based on cement clinker with blended compounds of grinded slag and limestone *PC 20M (S-L) 42.5R (CEM II/A-M (S-L) 42.5R)*, manufacturer Lafarge from Beočin, was used for the formation of the base material. River sand aggregate (*Moravac*), fraction 0/2 mm, was also used as natural aggregate for the preparation of the base mortar mixture. As lightweight aggregate, recycled crushed clay brick aggregate, fraction 2/4 mm, was added (Figure 1a). The recycled aggregate participated with 25% in the overall weight of the aggregate used in the mixture (Figure 1b). For the purpose of the base fibre reinforcement, polypropylene monofilament fibres *Sika Fibers* with the length of 6 mm, manufacturer Sika, were applied. As

² Embodied energy is the amount of energy consumed during the product life cycle, i.e., it includes the energy necessary for production, transport and disposal of certain products (US Department of Energy, n.d.).

additives, polymer latex *Sika Latex* and super plasticiser *Sika Viscocrete Techno 20*, manufacturer Sika, were used. As rock material, granite *Šutica* from Arandjelovac, which was cut to dimensions of 10 x 10 x 1 cm, was applied.

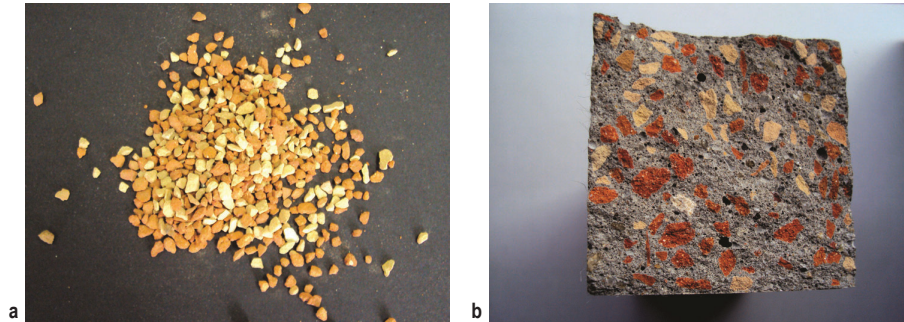


Figure 1: Used recycled aggregate and a produced sample of the cement composite: a) recycled crushed brick aggregate 2/4 mm, b) section of the mortar sample with recycled crushed brick as aggregate

MANUFACTURING OF THE FAÇADE COMPOSITE PANEL

The development of the pilot element - façade composite panel measuring 60 x 60 x 3.5 cm, was performed in the Laboratory of Materials, Institute of Materials and Structures, Faculty of Civil Engineering, University of Belgrade. The proposed façade panel is a prefabricated product. It is characteristic by a direct contact of stone with the fresh cement composite mixture³.

The manufacturing process started by placing the stone tiles (face down) on the bottom of the prepared mould (Figure 2a). The applied stone tiles were previously moistened, since the loss of water due to capillary absorption of stone might cause a decline of physico-mechanical properties of hardened mortar (Muravljev, 1983). They were immersed in tap water and placed surface dry just before the application of the mortar.

For the preparation of the mortar mixture, a mixer with fixed paddles was used. After homogenization of lightweight aggregate, cement and 2/3 amount of water, the last third of the water was added to the mixture. This method is proposed as the most favourable, since the lightweight porous aggregate absorbs considerable amounts of water during the mixing process (Pravilnik o tehničkim normativima, 1990). The lightweight aggregate was added dry to the mortar mixture. The fibres, superplasticizer, and polymer latex were added at the end of the mixing process according to the manufacturer's recommendations. The total duration of the mixing was extended to 4 minutes and 30 seconds for the purpose of evenly dispersing the fibres within the cement matrix.

³ In the world market, there are already widely deployed façade systems with glued stone coatings (epoxy resin is often used) to the base of the façade panel, which is previously a formed element.

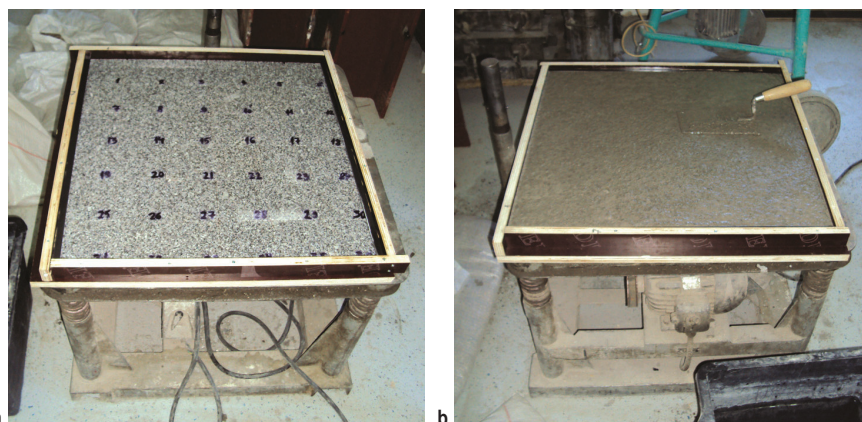


Figure 2: Preparation of the pilot element: a) mould with placed stone tiles, b) embedding the mortar on a vibrating table

The fresh mortar mixture was poured into the mould, over the previously placed stone tiles, and compacted mechanically on a vibrating table (Figure 2b). This kind of a dynamic action achieves very good embedding and compaction, as globules of air get extracted out of the fresh mortar, and the mortar fills out the entire space of a mould (Muravljov, 2010). After preparing, the sample was protected from drying out too quickly, in order to ensure optimal hydration and prevent damage due to rapid shrinkage (Pravilnik o tehničkim normativima, 1990). Curing of mortars modified with polymers differs to a certain extent from curing of conventional mortars, as formation of the polymeric matrix requires dry (air) and cement hydration requires wet regimen of curing (water). For the purpose of achieving optimal properties, the pilot element was subjected to a mixed regimen of curing, which consisted of 7 days in a humid environment (temperature of $20 \pm 2 \text{ }^\circ\text{C}$, relative humidity 95%) under damp jute cloth, and 21 days of curing in the air (temperature $20 \pm 2 \text{ }^\circ\text{C}$, relative humidity 65%) (Radonjanin, Malešev i Folić, 1999). The mould was removed with care 24 h after embedding. Figures 3a and 3b show the formed panel (after 28 days) with installed anchors, manufacturer Tabaš. The anchor gaps were formed during the prefabrication process of the panel, by inserting metal strips into two opposite sides of the mould.

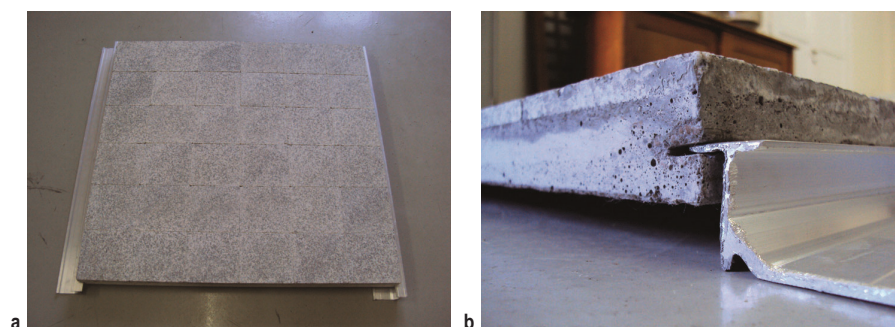


Figure 3: A façade panel on anchors, manufacturer Tabaš: a) a pilot element with installed anchors, b) a detail

DESIGN OPTIONS

Bearing in mind the production technology of a composite panel with a face of stone, it is possible to propose basic classifications of such a façade cladding (Table 1). Along with the described manufacturing technology, it is also possible to propose other manufacturing options. Stone tiles with a relief face surface could be placed in a mould in a wet sand base - face down, or they could be pressed in a fresh mortar mixture - face up (Otović, 1995). Joints could be made by applying plastic stencils to properly separate the stone tiles and form suitable joints (Krstić, 2003), etc.

Design of a façade envelope contributes to its surroundings with an aesthetic appearance and creation of a distinctive ambient. It should also represent the time period and place in which the building was constructed. These requirements, considering the addressed panel, could be met by the possibilities of different stone surface finishing. The natural appearance of a stone surface can be altered in terms of greater or lesser highlighting of its colour and structure by various processing procedures. Treatment methods could also affect some physical properties of a stone surface. They could improve or worsen properties such as water absorption and resistance to weathering (Bilbija i Matović, 2009). The applied stone tiles are relatively thin. Impact treatments are not recommended, because they can damage the internal structure of the rock. The tiles may be applied with a natural stone surface which could be smooth or rough. A flat surface can be obtained by cutting in the process of the primary cutting of blocks on boards. Sanded surfaces have a fine rugged appearance. Honed or polished surfaces fully emphasize colour and structure of the stone. Silicate rocks can be thermally treated. Sudden heating of a stone surface causes the formation of fractures and separation of fine parts. The depth of the relief depends on the mineral composition and structure of the rock (Bilbija i Matović, 2009; Crnković i Šarić, 2012), etc.

Table 1: The basic design classifications of the panel












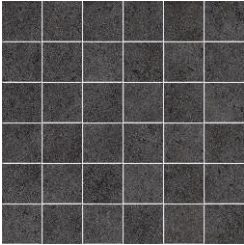

Classification according to the design pattern of the stone face		
Monolithic surface	Geometrical mosaic	Non-geometrical mosaic
		
Classification according to the finishing of the stone surface		
Recommended machine surface finishing	Natural surface finishing	
		

Table 1- continued

Classification according to the variety of the applied rock	
One rock type applied	Various rock types applied
	
Classification according to the variety of the applied surface finishing	
One type of surface finishing applied	Various types of surface finishing applied
	
Classification according to the relief	
Two-dimensional (2D)	Relief (3D)
	
Classification according to the treatment of the joints	
With visible joints	With "no joints"
	

CONCLUSIONS

In line with sustainable development in architecture and contemporary trends of waste management, the research is promoting recycling of building waste material. The study shows a possibility of using an environmentally friendly material such as recycled aggregate – in the case of the study crushed clay brick aggregate, to form a new building element – a prefabricated façade panel with the face of stone. The proposed panel can be used within a ventilated façade system. The design possibilities of the façade panel depend on the various appearances of its stone face.

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