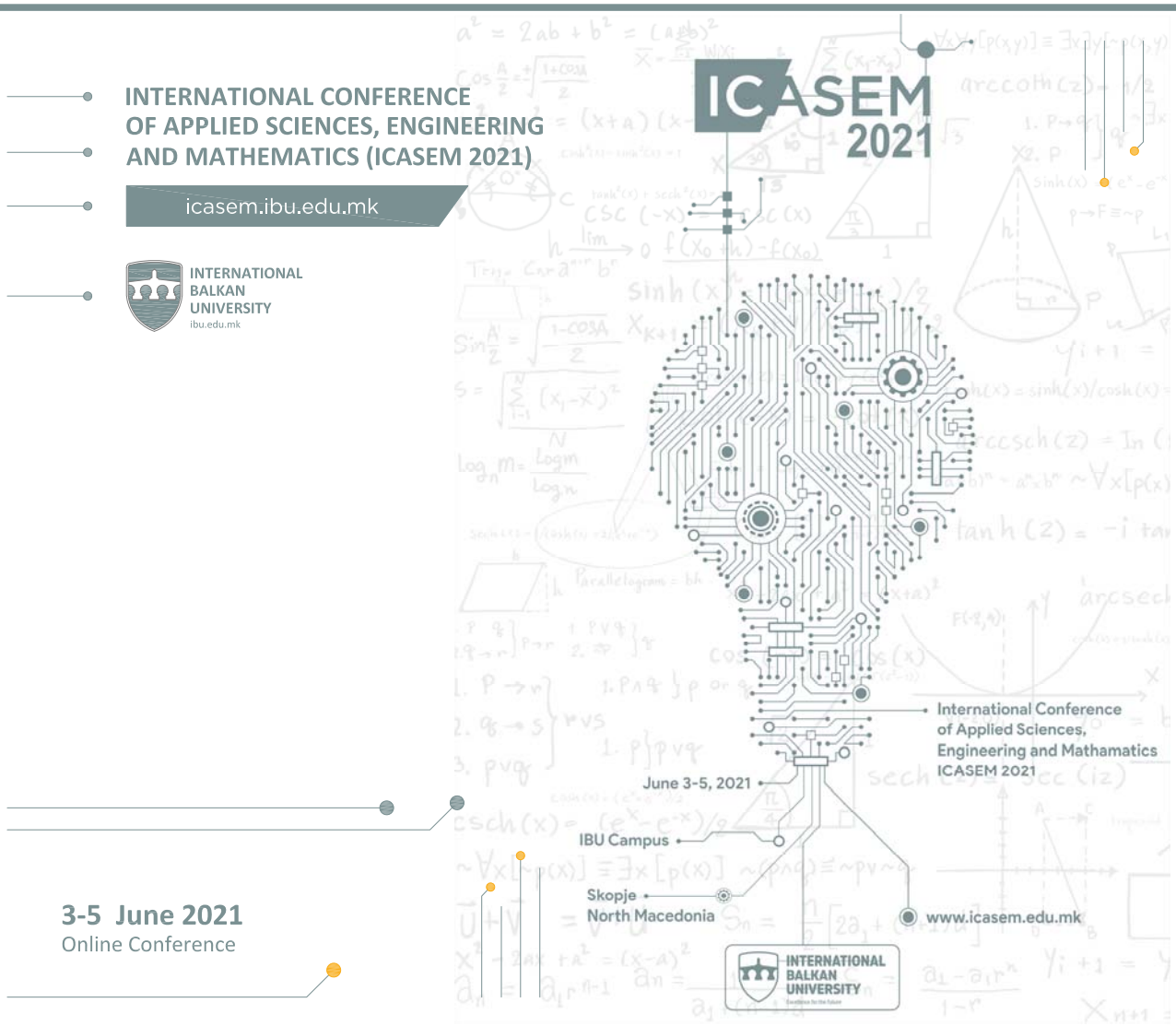

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International Conference of Applied Sciences, Engineering and Mathematics

3-5 June 2021

E-conference, R. North Macedonia

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1. Keynote speakers

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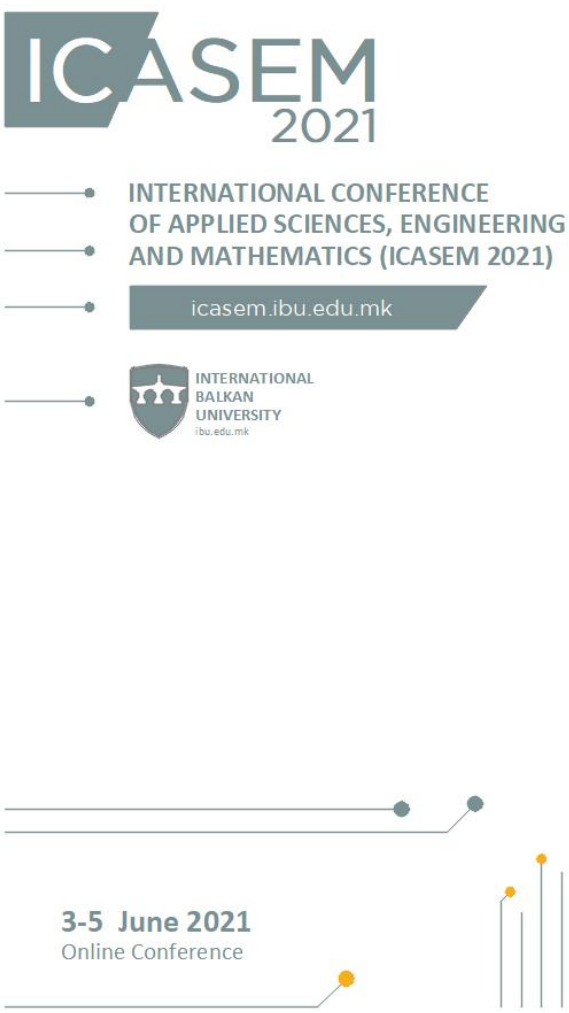

Resume:

Lidija Petkovska has received BSc EE Degree from the Faculty of Electrical Engineering, University of Belgrade, and MSc EE and Doctoral Degree from the Faculty of Electrical Engineering, Ss. Cyril and Methodius University of Skopje.

Her field of interest encompasses wide problems of electrical machines, which are principally in three areas: novel electrical machines, electric drives and control, and in particular numerical FEM field computations of electrical machines, design, optimization, simulation and testing.

Until 2008 Lidija Petkovska was full professor with Faculty of Electrical Engineering and Information Technologies from Ss. Cyril and Methodius University of Skopje. From 2009-2013 she was full professor with International Balkan University in Skopje, serving from 2011 as Dean of the Faculty of Graphic Design. During her educational career, she was delivering lectures on numerous courses of all three cycles of study, guiding more than 150 diploma projects, 8 master and 4 doctoral theses. Another important part of her activities is participation in total 28 international and/or domestic Science&Research, Research&Development, Industry oriented and Educational projects, acting in 11 as principal researcher and team leader.

Professor Lidija Petkovska has an international reputation on all of her research work. She has published as author and co-author 295 papers in conference proceedings and 76 peer reviewed papers in scientific journals, among which 35 are with impact factor. Lidija Petkovska in 1995 published a book “Micromachines”, dealing with small and special electrical machines, still the only one in the country.

As a recognition to her scientific work she was delivering guest lectures for PhD students at the University of Lodz, Poland and for MSc students at the University of Maribor, Slovenia. Also, at ISEF’2013 Conference presented an invited paper, while at ISEF’2019 she was one of the panellist at the session entitled “Optimal design, metamaterials, 3D printing” giving a speech on “Shape synthesis and innovative motors”.

Lidija Petkovska is a member of ISCs of prestigious international conferences, acting as a peer reviewer and also chairing more than 70 sessions. She was organizer and Chair of the world-wide known ISEF’2013 conference, and from 2006 is founder and chair of SAEM conference, now in the 8th edition – SAEM’2022, which will be held in North Macedonia.

Lidija Petkovska is Senior Member of IEEE and member in two societies: Power and Efficiency Society – PES and Magnetic Society. She is also member of Polish Society of Applied Electromagnetics – PTZE (PSAE), honorary member of Macedonian Section for power electronics, drives and control MAK-ZEEPU, member of CIGRE International and the Chair of CIGRE-North Macedonia B4 Committee.

Keynote Speaker

Prof. Dr. Lidija Petkovska

International Balkan University, Skopje, North Macedonia

State-of-the-Art Technology for Innovative Electric Motors

Electric motor is one of the few inventions that shaped electrical technology the most. The very beginning of the electric motor is found exactly two hundred years ago, in 1821. However, over the time many significant changes in the technology have been moving forward, opening new frontiers for innovative electric motors. In particular, new trends in e-mobility as the developments of EV (Electric Vehicles) and HEV (Hybrid Electric Vehicles), forced new requirements related to size/weight of the drive and resulted in awesome innovations for in-wheel electric motors, thus creating substantial solutions.

The first question to be answered is "What makes an electric motor innovative?" First, it is an innovative design topology and use of novel materials, then an innovative production technology and, the most recently, new state-of-the-art manufacturing processes. A design engineer of electric motors is seeking for answers to the following: (i) What are structural/shape choices that define novel motor topology and make the motor better-performing? (ii) What are the most effective novel materials for obtaining the best of each component/shape in the design layout? (iii) How to extend the limits of the motor's performance reached today? (iv) What are novelties in the electric motor design? (v) How is an innovative motor manufactured?

Another important aspect to discuss is certainly the state-of-the-art production technology. The most recent 3D printing technology developments, have added a huge value to the designing, prototyping as well as manufacturing processes. The broad spectrum of production applications has been unlocked. The significant reduction of time and money consumption, required for the stage of prototyping, led to cost-effective massive motor production. The laser technology is growing, becoming more workable and affordable, such that additive manufacturing (AM) from 3D printing of only parts of an electric motor has been moved to the printing even the whole motor structure. Using 3D computer aided design (CAD), and having in hand 3D scanners, additive manufacturing allows the creation of objects with precise geometrical shapes, built layer by layer with adding multi-material, opposite to classical manufacturing when the excess of material is subtracting.

The AM technology is broadly divided in three types: (i) sintering whereby the material is heated without being liquified to create complex high resolution objects; (ii) melting where metal powders are melted so that the particles stick together and shaped; (iii) stereolithography, which uses the process of photopolymerisation, to create torque-resistant ceramic parts. In the talk few selected processes are discussed and elaborated: Fuse Deposited Material (FDM), Selective Laser Sintering/Melting (SLS/M), StereoLitography Apparatus (SLA).

To present days several pioneering research centres throughout the world have reported successful applications. At the end of this talk, more interesting applications are presented. It is started with the earliest practical implementation of 3D printing for the purpose of electric motor prototyping in e-mobility, where only some parts of the motor topology have been manufactured. However, the real challenge for electric motor designers is producing the whole motor by using AM, the task still rather complicated. The first fully 3D-printed stator, developed by an enthusiastic group of electrical engineers from Chemnitz University, Germany and premiered in 2018 at 'Hannover Messe' – the trade fair, will be presented and explained.

Keywords:
Innovative motors; E-mobility; Novel materials; 3D-Printing; Additive manufacturing (AM); Fuse Deposited Material (FDM); Selective Laser Sintering (SLS); StereoLitography Apparatus (SLA)

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3-5 June 2021
Online Conference

KEYNOTE SPEAKER

Prof. Dr. Damir Varevac

Josip Juraj Strossmayer University, Osijek, Croatia

Title:

Combination of Destructive and Non-destructive Methods for Testing of Existing Structures – Case Studies

Resume:

Damir Varevac has received his MSc degree in Structural Engineering at Faculty of Civil Engineering in Zagreb, University of Zagreb and PhD degree in Structural Engineering from Faculty of Civil Engineering and Architecture Osijek, University of Josip Juraj Strossmayer in Osijek.

He is a licensed civil engineer, member of Croatian Chamber of Civil Engineers. He is involved in implementation of Structural Eurocodes in Croatia for more than 15 years as a member of Technical Subcommittee 548/2 “Design of concrete structures” and 548/8 “Design of structures for earthquake resistance” in Croatian Standards Institute. He is currently the president of Technical Committee 548 “Structural Eurocodes” in CSI and member of the CEN TC250/SC8 Working Group 6 “Bridges” for preparing new draft of EN 1998-2.

Damir Varevac is full professor at Faculty of Civil Engineering and Architecture Osijek and currently is serving as Dean of the Faculty. He teaches the courses related to reinforced and prestressed concrete structures and bridges. His current field of interest is impact of explosions on engineering structures and testing of the structures with destructive and non-destructive methods. In his work he integrates traditional and state-of-the art techniques for evaluating existing structures, such as forced and ambient vibrations, ultrasound techniques and especially application of the ground penetrating radar, both in structural engineering as well as in archaeology and preservation of cultural heritage.

Keynote Speaker

Prof. Dr. Damir Varevac

Josip Juraj Strossmayer University, Osijek, Croatia

Combination of Destructive and Non-destructive Methods for Testing of Existing Structures – Case Studies

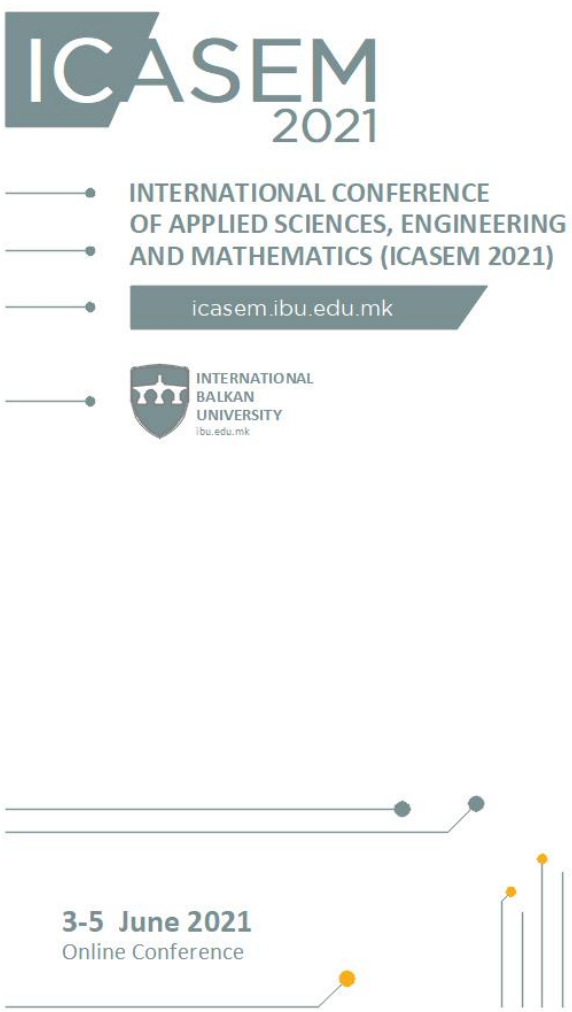
There are a number of reasons why existing structures need to be tested. In this presentation, I will try to explain these reasons and show examples from practice. In our experience, the reasons for testing structures can be divided into the following main groups: new structures of large span, unusual static systems, or of new innovative materials; existing structures to be upgraded; structures damaged by deterioration or accidental actions; new structures that have no evidence of the quality of the materials. Each structure requires a separate approach and a set of specific methods to be applied to obtain the most useful results.

In general, test methods can be destructive and non-destructive. Each of them has its advantages and disadvantages, and the most useful approach is a combination of these methods. Several examples will show how the structure testing team of the Faculty of Civil Engineering and Architecture Osijek approaches the examination of structures and the methods it uses. These methods are a combination of classical methods (core drilling, sclerometer), but also intensive use of the most modern methods such as ultrasound, georadar, and dynamic methods of measuring ambient or forced vibrations of the structure. The final result of these tests must always give an answer about the usability and safety of the structure.

In addition to cases of structural testing, a brief overview of our experiences of applying georadar in other areas will be given.

Keywords:

Testing of Structures; Diagnostic; Building materials; Defects; Ultrasound; Georadar



Resume:

Energy and resource efficiency strategist, consultant and trainer. Helping businesses, both commercial and industrial companies across five continents, maximise their energy and resource efficiency; identify the minimum investment cost pathways; and reduce the often complex and technical messages in to a clear, meaningful and simple-to-understand business case.

Having worn many hats in his 24-year career – design, technical operations, management, consultancy, equipment supplier, energy performance contracting, training, and in policy development – he has a unique ability to understand technical and managerial challenges, work with different stakeholders, manage multi-disciplinary projects, identify opportunities for improvements, and troubleshoot performance deficits. His work helps managers to engage with senior executives, disarm barriers for performance improvement, and bring about its implementation in a safe and healthy manner.

He also trains new and aspiring professionals, and in-company energy and resource efficiency champions in ISO 14001 environment management system, ISO 45001 occupational health and safety management system, ISO 50001 energy management system, integrated management systems, ESOS lead assessor qualification, at British Standards Institution (BSI), and Institution of Chemical Engineers (IChemE).

He volunteers in IChemE's Congress, IChemE's Energy Community of Practice, IChemE's annual sustainability awards judging panel, UNIDO's global energy management leadership awards judging panel, and takes part in developing Nationa, Regional and International standards. He chaired ISO 14002-2 (current), ISO 50002 (current), PAS51215, EN16247-3, and participated in the development of ISO 14001 series, ISO 50001 series, and EN16247 series of standards.

Keynote Speaker

Kit Oung,

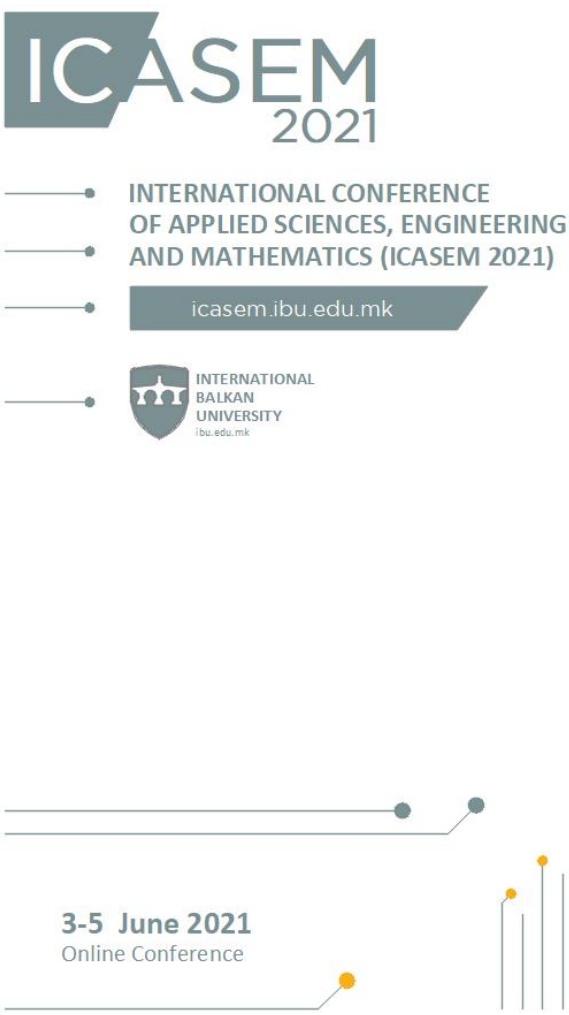
M.Sc.(Eng.), C.Eng, MIChemE,
Chartered Energy Manager, MEI, F.EMA

Godalming, England, UK

Energy and Resource Efficiency: What Can Scientists and Engineers Do?

The main aim of this presentation is to give an overview of the current state of play for energy and resource efficiency and the things that scientists and engineers can do to reduce energy and resource consumption, use them responsibly, minimise their environmental impact, and avoid irreversible climate change.
It covers the current understanding of why the application of energy and resource efficiency is much slower in real corporations than the available technologies and know-how. This is used to identify the broad actions that needed to be addressed in order to adopt and accelerate energy and resource efficiency.
Moreover, the presentation gives an overview of the life cycle of a corporation - its products and services - ranging from concept, design, through to the end of life, and highlights the actions scientists and engineers contribute at each of the life cycle stages.
Finally, the presentation rally participants to think about and declare the actions they will take to accelerate energy and resource efficiency.

Keywords:
Energy and resource efficiency; State of the art; Energy and resource consumption; Environmental impact; Climate change



Resume:

Maria-Beatrice Andreucci has received a MSc in Financial Economics from the Faculty of Economics, LUISS University (Rome, Italy); a Master of Business Administration from INSEAD (Fontainebleau, France); a MSc (cum laude) in Architecture from "Sapienza" University of Rome (Italy) and a Doctoral Degree "Doctor Europaeus" in Environmental Design from the Department of Planning, Design, Technology of Architecture, "Sapienza" University of Rome, Italy. She is a registered architect and an economist and focuses her professional activity, research and teaching on the application of environmental technological design and environmental economics theories, principles and methods on urban design and architecture projects. In both teaching and researching, she levers on an extensive international professional experience in strategic planning and economic valuation, working on complex, integrated business development and corporate finance projects, consulting leading private and public institutions and corporations worldwide. Research works led her to Europe, China and the USA for cross-cultural research on urban transition and climate-adaptive design.

Multidisciplinary approach, extensive international networking and research-through-design characterize her activities that she carry-on actively participating to national and international EU funded projects. She is Management Committee Member, representing Italy, of the Cooperation in Science and Technology COST Action CA19126 "Positive Energy Districts European Network" (2020-2024) that will drive the deployment of Positive Energy Districts (PEDs) by harmonizing, sharing and disseminating knowledge and breakthroughs on PEDs across different stakeholders, domains and sectors at the national and European level. In the "PED-EU-NET" COST Action she is also leading the working group responsible for "Dissemination, Outreach and Exploitation".

Maria Beatrice Andreucci is a Steering Board member, expert and leader of the thematic working group "Urban Economies and Welfare" in JPI-UERA "Urban Europe Research Alliance" (since 2017); and Chair of IFLA "International Federation of Landscape Architects Advisory Circle". She is member of EDRA "Environmental Design Research Association"; and SITdA "Italian Society of Technology of Architecture".

In the last five years, she has published 4 books, and more than 60 articles in scientific journals, and has delivered 45 speeches at international conferences and workshops. Her design projects have been published in international journals and have won recognitions and prizes at international levels. Currently, she works as a Research Professor in the Doctoral Programme in Environmental Design, member of the Faculty of Architecture, and member of the Scientific Didactic Committee of the II level Master in Environmental Technological Design, at the Department of Planning, Design, Technology of Architecture of "Sapienza" University of Rome.

Keynote Speaker

Prof. Dr. Maria-Beatrice Andreucci

Sapienza Università di Roma, Rome, Italy

The Sustainability Transition in Europe in an Age of Environmental, Human and Technological Change. A Journey into Experiences and Perspectives

Before the world was impacted by COVID-19, progress towards the 2030 UN Sustainable Development Goals (SDGs) was already uneven, and a more focused attention was needed in most SDGs target areas. The pandemic abruptly disrupted plans and efforts towards urban transition, in some cases reverting decades of progress. The concept of resilience changed in 2020 and having to face severe health issues combined with increased socio-economic challenges in a climate change scenario, cities must urgently explore how to best combine environmental goals with economic recovery and social justice, modifying on-going plans and initiatives, while re-arranging priorities. Acknowledging the impact that the pandemic will produce, for the years to come on processes and initiatives towards a regenerative economy, this keynote will describe most recent strategies aimed at sustainability transition in Europe, and critically discuss available options with respect to implementation and funding, within the framework of selected UN SDGs. Reached conclusions challenge the ability of our modern society to put in practice the needed urgent actions and call for a paradigm shift to prepare Europe to deal with climate disruptions, activate transition to a healthy and prosperous future within the planetary boundaries, and scale up solutions that will trigger transformations for the benefit of people and the environment.

Keywords:
COVID-19; Sustainable Development; Urban transition; Pandemic; Climate disruptions

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2. Electrical and electronics engineering

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Comparison of COVID-19 Prediction Performances of Normalization Methods on Cough Acoustics Sounds

Yunus Emre Erdoğan[1, 2], Ali Narin[2]

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[1, 2]Electrical and Electronics Engineering Department, Zonguldak Bülent Ecevit University, 67100, Zonguldak, Turkey

[2]Electronic Automation Department, Eregli Iron and Steel Inc., Zonguldak, Turkey

Abstract:

The disease called the new coronavirus (COVID19) is a new viral respiratory disease that first appeared on January 13, 2020 in Wuhan, China. Some of the symptoms of this disease are fever, cough, shortness of breath and difficulty in breathing. In more serious cases, death may occur as a result of infection. COVID19 emerged as a pandemic that affected the whole world in a little while. The most important issue in the fight against the epidemic is the early diagnosis and follow-up of COVID19 (+) patients. Therefore, in addition to the RT-PCR test, medical imaging methods are also used when identifying COVID 19 (+) patients. In this study, an alternative approach was proposed using cough data, one of the most prominent symptoms of COVID19 (+) patients. The performances of z-normalization and min-max normalization methods were investigated on these data. All features were obtained using discrete wavelet transform method. Support vector machines (SVM) was used as classifier algorithm. The highest performances of accuracy and F1-score were obtained as 100% and 100% using the min-max normalization, respectively. On the other hand, the highest accuracy and highest F1-score performances were obtained as 99.2 % and 99.0 % using the z-normalization, respectively. In light of the results, it is clear that cough acoustic data will contribute significantly to controlling COVID19 cases.

Keywords: *COVID19; cough; Discrete wavelet transform; Z-normalization; Min-max normalization*

1. Introduction

The novel coronavirus disease (COVID19) is a recent viral respiratory disease that was first identified on January 13, 2020 in Wuhan, China, with high fever and shortness of breath. It is known that the disease is transmitted by droplets and contact. It is defined as a pandemic because of the global epidemic situation it creates [1, 2]. The virus that induces the COVID19 pandemic is a serious acute respiratory syndrome coronavirus-2. (SARS-CoV-2) [3]. Symptoms of the new coronavirus infection can contain fever, cough, shortness of breath and difficulty breathing.

In more serious circumstances, the infection can induce pneumonia, acute respiratory insufficiency, kidney insufficiency and even decease [4]. It is also known that symptoms such as low lumbar pain, exhaustion, runs, queasiness, cephalagra and giddiness are seen [5].The identification of the virus can be made either directly to detect the virus, or by showing the specific antibodies that the host organism creates against the virus. In this direction, there are two test categories used in laboratories. These are the PCR test, which detects the virus itself, and the antibody test, which detects the host's response to the virus. In addition, lung tomography and some blood tests are utilized additionally in the identification of the illness [6]. These PCR tests have been annoying, time absorbing and those outcomes are lagged [7]. For this reason, approaches on the grounds that the analysis of cough acoustics sounds are utilized in together with this test [8]. Study on cough acoustics sound analysis were added to the literature.

Approaches on cough sounds for identifying COVID19 sicks are as indicated below: Erdoğan and Narin used cough acoustic data in their study. They used z-normalization technique for preprocessing. In the study, they used IMF and DWT based feature extraction via traditional learning techniques and they utilized SVM as classification method [9]. They also added deep features to this study. Here they used deep features on the RESNET50 deep learning model. In other research, Imran and colleagues tried to determine COVID19 sicks by examining cough sounds in a study named AI4COVID19. They engaged mean normalization technique in the research. They got images, which are Mel-spectrogram, for the Convolutional Neural Network pattern. For the traditional machine learning approach, they utilized Mel-frequency cepstral coefficients and Principal component analysis basis on feature extraction and Support Vector Machines classification method [10].

In this research, time domain and nonlinear features were taken via utilizing the 5-Layer discrete wavelet transform process utilizing cough sounds from people with COVID19(+) and COVID19(-) as shown in Figure 1. Z-normalization and min-max normalization were used as preprocessing method. In this study, which was carried out with the traditional machine learning approach, the support vector machine algorithm was used. In the second part of the study, the data set used, the details of the methods and techniques are given, the results obtained in the third part are given, while the findings obtained from the studies in the literature are discussed in the fourth part.

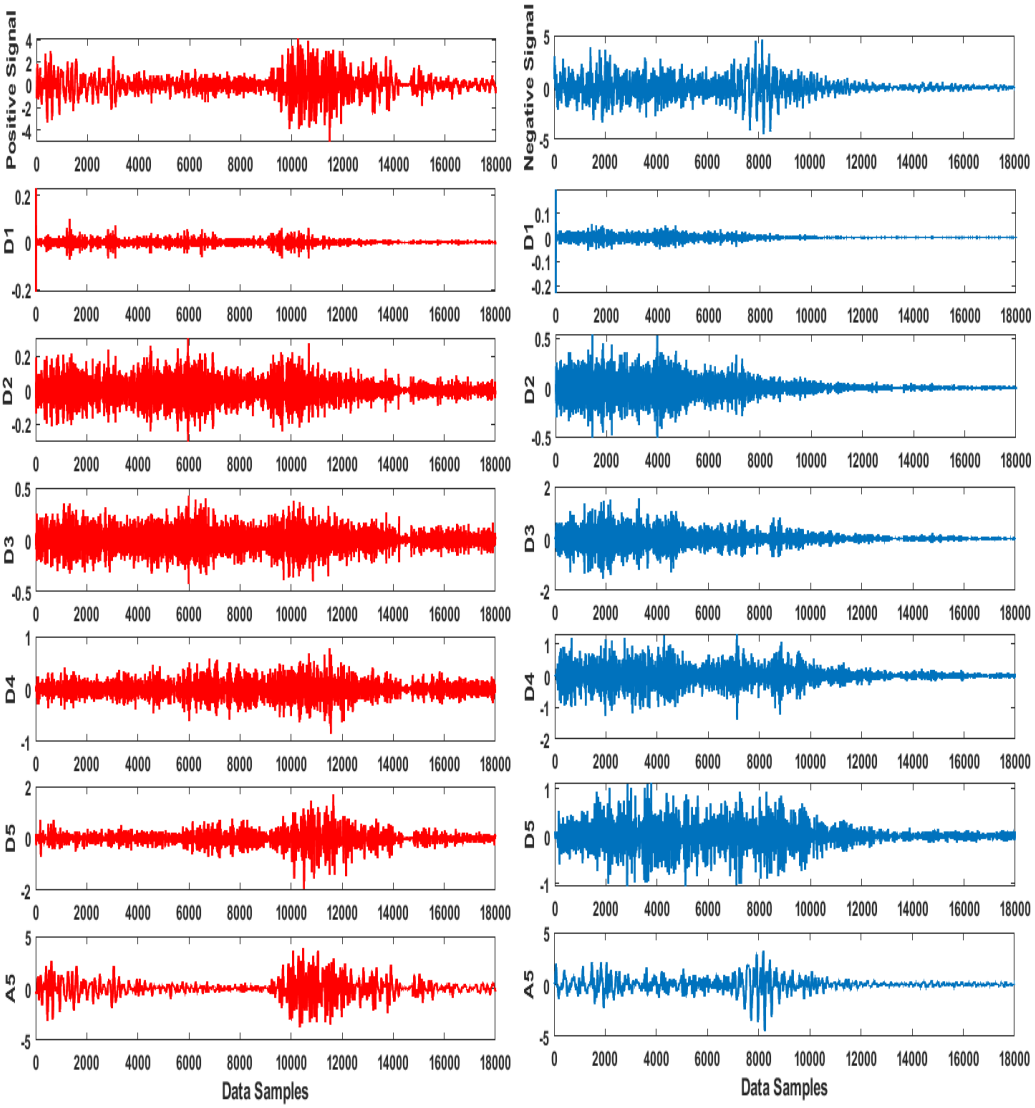

Figure 1 *COVID19 (+) and COVID19 (-) cough acoustics data and 5-Layer Discrete Wavelet Transform coefficients*

2. Methods

2.1. Dataset

Cough sounds of people who are COVID19 (+) and are COVID19 (-) have been taken from https://virufy.org/. The data was collected with a mobile based application builded up via Stanford University. The cough sounds pertain to a sum of 16 people and 6 of these people are females and 10 of them are males. These group of people has 42 age as average. All data have been stated as positive and negative pursuant to the outcomes collected from PCR test. As a conclusion of these tests, COVID 19 (+) was 7 of these group of people and 9 of them were COVID 19 (-).These results were tagged. Most people tagged as COVID19 (+) have signs like difficulty in breathing, sore throat, and cough. Some of them suffer from congestive heart failure, asthma, diabetes, and in some others have a loss of taste and smell, fever, and chills. Only one of the people labeled COVID19 (-) have chronic diabetes and a few have complaints of difficulty of breathing, throat ache, body aches and worsening cough. The data on the platform from which it was obtained was segmented and made ready for the use of researchers. From these data, 9 COVID19 (-) labeled cough acoustic data were divided into 73 parts, 7 COVID19 (+) labeled cough acoustic data were divided into 48 parts. The sampling frequency of each piece of data is 48 kHz, and the coughing time has been determined as 1640 milliseconds (ms). In addition, all the data were standardized with the z-score method before the study carried out.

2.2. Z-Normalization

Z-score converts mean of variable to 0 and its standard deviation to 1. To do this, simply subtract the mean and divide by the standard deviation. The z-score normalization can be calculated as [11]:

$$z = \frac{x - m}{sd} \quad (1)$$

Where x indicates any point in the dataset, m indicates mean of the dataset, and sd indicates the standard deviation of the dataset.

2.3. Min-Max Normalization

In the min-max normalization process, the features are normalized between 0 and 1 according to the equation below [11]:

$$v' = \frac{v - min_X}{max_X - min_X} \quad (2)$$

Here, min_x is the minimum value of the x feature and max_x is the maximum value of the x feature. The original and normalized values of the x feature are denoted by v ve v', respectively. It can be seen from the above equation that the minimum and maximum attribute values are equal to 0 and 1, respectively

2.4. Discrete Wavelet Transform

Process of the continuous wavelet transform is the sum of the signal which is multiplied by its shifted and scaled types in the time plane of the main wavelet during time. As a conclusion of these operations, wavelet coefficients based upon the position and the scale are found. Provided that scaling and translation are preferred as powers of 2 analyzes are more effective than continuous wavelet transform and gives as accurate results as it. This kind of analysis is called the discrete wavelet transform [12].

2.5. Support Vector Machines

SVM is a classification method on the grounds that statistical theory. The mathematical algorithms of the SVM were initially designed for the classification problem of two-class linear data, then generalized for the classification of multi-class and non-linear data. The working principle of SVM is based on estimating the most appropriate decision function that can distinguish two classes from each other, in other words, defining the hyper-plane that can best distinguish two classes from each other [13].

2.6. Performance Metrics

In this study, the results were evaluated using five different performance measures [14, 15]. These:

$$Accuracy(ACC) = \frac{TP + TN}{TP + FN + FP + TN} \quad (3)$$

$$Recall(\ REC) = \frac{TP}{TP + FN} \quad (4)$$

$$Specifity(SPE) = \frac{TN}{TN + FP} \quad (5)$$

$$Precision(PRE) = \frac{TP}{TP + FP} \quad (6)$$

$$F1 - score(F1) = \frac{2 * PRE * REC}{PRE + REC} \quad (7)$$

TP=True Positive, FP=False Positive, TN=True Negative, FN=False Negative

TP shows the people ,who are COVID19(+), number and identified as COVID19(+) by the classifier, FN is the number of people who are wrongly stated as COVID19(-), TN the people number, who are actually COVID19(-),and the classifier were stated them as COVID19(-), and FP shows the people number ,who are mistakenly identified as COVID19(+) [16].

3. Experimental Results

In this research work, the preprocessing of the cough sound signals taken, the features taken with traditional machine learning methods, extraction operation of the features obtained and taken of the performance values have been experimented via MATLAB 2020 computer programme. Both normalization methods utilized in this research, traditional machine learning processes have been engaged. Then, 54 DWT based measures were found from the signals taken as a conclusion of min-max normalization and z-score. The confusion matrix of z-normalization, the highest performance result from the results obtained with the features extracted by traditional approaches is given in Figure 2. It is clearly seen that while all the ones in the COVID19 (+) class were detected correctly, only 1 of the ones in the COVID19 (-) class were detected incorrectly. For min-max normalization, all of the COVID19 (+) and COVID19 (-) classes have been correctly identified.

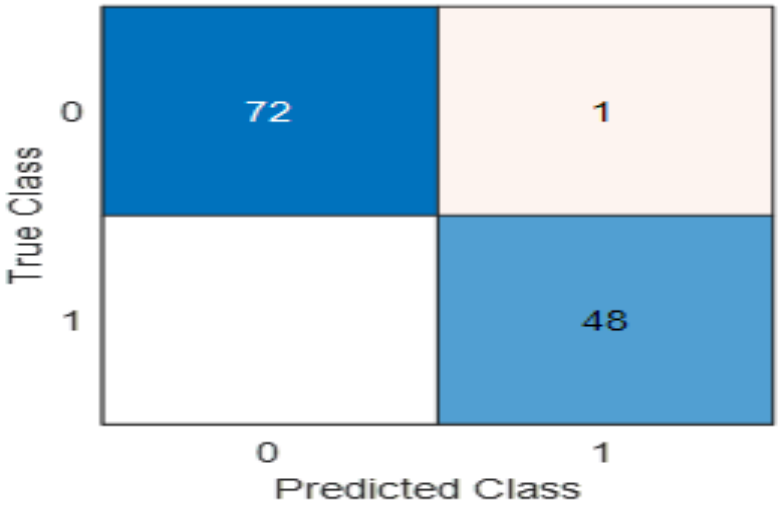

Figure 2 Z-score confusion matrice with highest performance

4. Discussion

No doubt one of the most researched topics in the last few years is the coronavirus epidemic, which affected all over the world. The most vital point in overcoming this epidemic is the process of making the correct diagnosis. Therefore, there are many machine learning-based studies in the literature [17]. The detection of COVID19 (+) through cough acoustic signals, which suggests a different approach, has recently taken its place among the current alternative methods. Performance metrics comparisons of those using normalization methods among the studies conducted in this area are given in Table 1. Traditional machine learning approaches and feature extraction processes were generally used in these studies. In some studies, in addition to traditional machine learning approaches, deep learning approaches have been used to detect COVID19 (+) people based on cough sounds. In this study, the performances of two different normalization methods were analyzed over the features obtained with traditional machine learning approaches. With these two alternative approaches, which work with a very high success rate, a decision support mechanism has been recommended to experts for the detection of COVID19 (+) people.

In addition to the detection of COVID19 (+) with imaging methods, it is of great importance to detect these people with cough-based acoustic sound analysis. With this method, the detection of COVID19 (+) can be easily achieved via a smartphone or computer application. With this application, the

pandemic can be overcome more easily. From this point of view, it is of great importance that even a single person can be protected from the epidemic during the pandemic. We think that such systems showing high performance will be of importance during pandemic period. One of the most critical restrictions of this research is the limited number of data. By enhancing the number of data near future, it is thought that the system will be successful on high data numbers. In future studies, it is planned to increase the number of nonlinear measurements.

Table 1 COVID19 detection with normalization techniques using acoustics signals in the literature

Authors	**Methods and Classifiers**	**Number of Data**	**Performance (%)**
Imran et al. (2020) [10]	Mean Score + Mel-frequency cepstral coefficients and Principal component analysis / Support Vector Machines	543	Rec=96.0 Spe=95.2 Acc=95.6 F1=95.6
Erdogan and Narin(2021) [9]	Z-Score + Intrinsic Mode Functions and Discrete Wavelet Transform features + Support Vector Machines	1187	Rec=99.5 Spe=97.4 Acc=98.4 F1=98.6
Erdogan and Narin(2021) [9]	Z-Score + ResNet50 basis deep features + Support Vector Machines	1187	Rec=98.5 Spe=97.3 Acc=97.8 F1=98.0
This study	**DWT based features + Min-max Score/Support Vector Machines**	**121**	**Rec=100 Spe=100 Acc=100 F1=100**
This study	**DWT basis features + Z Score / Support Vector Machines**	**121**	**Rec=100 Spe=98.6 Acc=99.2 F1=99.0**

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Design of ARM Microcontroller Based Electromagnetic Water Flowmeter

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Abstract:

The aim of this study is to develop an ARM Microcontroller based electromagnetic flowmeter to be used in water flow monitoring tasks. In this study, electromagnetic water flowmeter system proposed based on ARM Microcontroller. In this proposed system, square wave excitation signal used in magnetic field generation and measurement algorithm implemented based on this excitation signal. The proposed system constructed based on three elements which are electromagnetic water flowmeter sensor, signal converter and STM32 development board. The analog electromotive force readings from sensor model continuously taken, and processed using IFC 100 signal converter. This processed electromotive force readings forwarded to STM32 development board to be used in measurement algorithm that is embedded into the development board. The sensor flow readings tested on various flow levels during the studies, the working principle of electromagnetic water flowmeter is examined, and the results are presented.

Keywords: *Electromagnetic Water Flowmeter, Square Wave Excitation, ARM Microcontroller, Measurement Algorithm*

1. Introduction

Electromagnetic flowmeters are flow measurement devices that works based on induced electromotive force which resulted from conductor moving through a magnetic field [1]. EMFM materials can be configured to fit different application conditions such as application with different liquids and gas being measured. In this regard, EMFMs are widely used in various sectors including wastewater, food and beverage, and blood flow [2-4]. EMFMs works based on Faraday's electromagnetic induction law to compute flow rate of liquid inside the measurement pipe [5]. The visualization of this working principle including EMFM sensor model is shown in Figure I-1. EMFM sensor model consists of three main elements that are pair of electrodes, measurement pipe with liner and excitation coils.

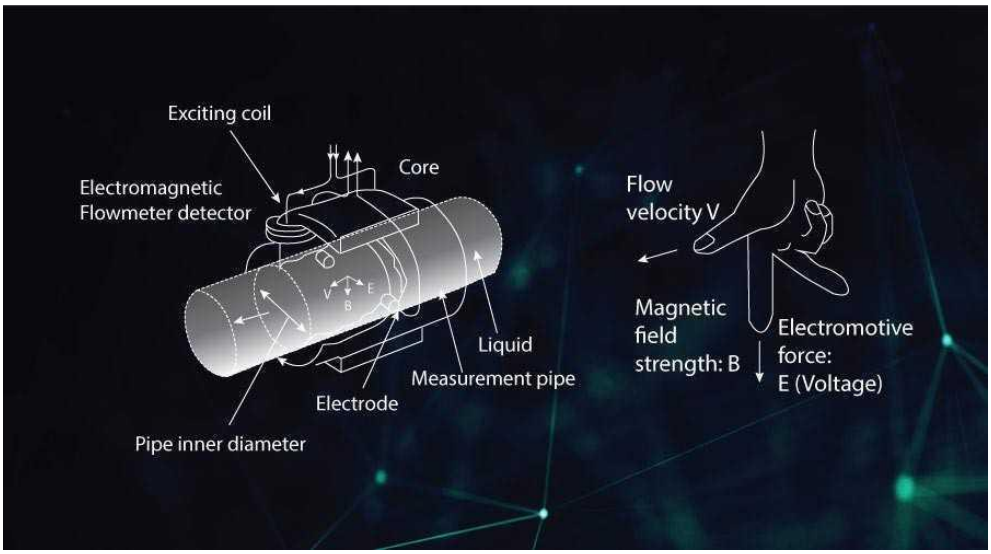

Figure 1 Working Principle of Electromagnetic Flowmeter [6]

Besides working principle, EMFMs used in various combinations based on excitation coil, excitation signal and electrode configurations. Permanent magnets as magnetic field source is an example used in the EMFM system [7]. There are also various excitation signal configurations used in EMFMs that are AC sinusoidal excitation signals, DC rectangular biphasic signals and double-frequency signals [8-10]. In this study, the square wave excitation signal used for generating magnetic field throughout the measurement pipe. In addition, measurement algorithm implemented based on this excitation signal.
The rest of the study is presented in the following manner: in the materials and method section software and hardware components that have used during the project are explained and introduced. In method section, hardware, and software designing process and methods that have been used are explained. In results section, model results introduced. In the last section, conclusions and recommendations of the study are presented.

2. Materials and method:

The overall system consists of STM32F407VG development board [11], Krohne IFC 100 Signal Converter [12] and flowmeter sensor which contains coils to obtain magnetic field, measurement pipe with 20 mm diameter and pair of electrodes to sense generated electromotive force in hardware implementation and measurement algorithm in software implementation. The proposed system is established in order to monitor flow inside the measurement pipe.

2.1. Hardware Implementation

In flow sensor model, the pair of electrodes placed at the center of measurement pipe, and in same horizontal level in order to sense balanced induced electromotive force on each electrode, and represent maximum amount of liquid volume. The material used in electrodes is nonmagnetic 304 stainless-steel

to prevent negative effect of magnetic field on electrodes and by considering its compatibility with water flow monitoring applications. The measurement pipe has diameter of 20 millimeter and constructed using Delrin, which is good insulator and compatible material with water flow monitoring applications. The coils located at the top and bottom of the measurement pipe and each contains 1000 turns and 105 Ohm's resistance. This structure of the proposed flow sensor model is shown in Fig.2.

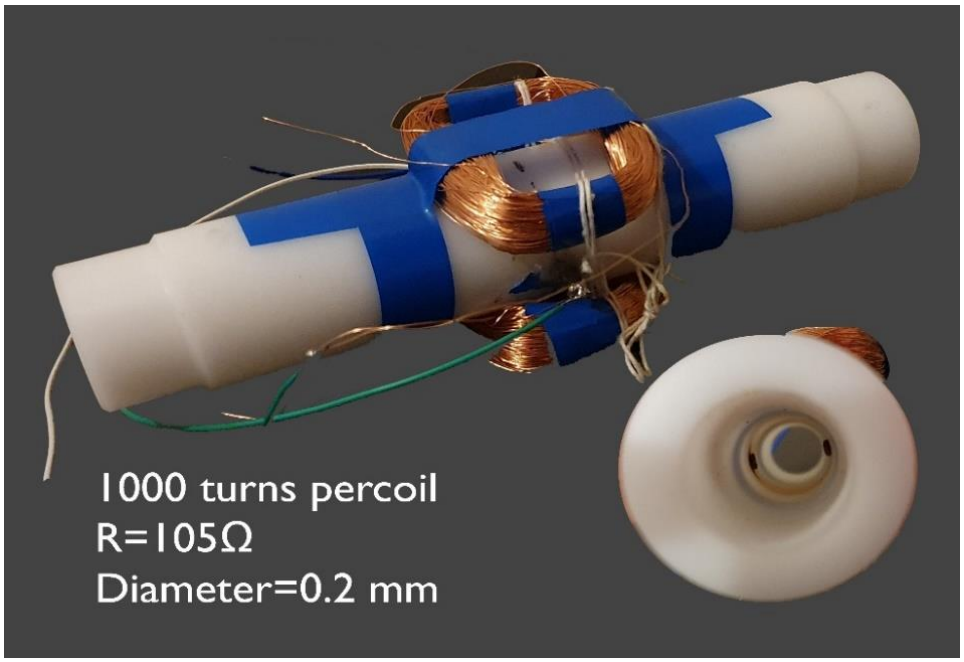

Figure 2 *Sensor Model Overview*

IFC 100 Signal Converter shown in Fig.3. used in order to preprocess the induced electromotive force, supply excitation signal to coils located at measurement pipe and forward processed voltage readings to STM32 development board to be used in flow calculations. It contains 24-bit differential input analog to digital converter for analog electrode readings and excitation circuit to supply 8.25 Hz square wave excitation signal to coils located at measurement pipe [12].

Figure 3 *IFC 100 Signal Converter*

The STM32F407VG development board shown in Fig.4. used in flow computations. It offers affordable and accessible way for users to create projects and prototypes with the provided features, high performance capability and GPIO availability for different usage combinations. The preprocessed induced electromotive force readings from signal converter forwarded to this development board for flow computations. The measurement algorithm embedded into this development board and flow computed based on induced electromotive force readings of flowmeter sensor model.

Figure 4 STM32F407VG Development Board

2.2. Measurement algorithm

Measurement algorithm developed based on the excitation signal waveform. Using the 8.25 Hz square wave excitation signal, direction of magnetic field generated through measurement pipe changes in every 60 milliseconds. Sensed induced EMF changes its level by this change in magnetic field direction and the difference between these potential differences mostly occurs due to velocity of liquid inside the pipe. Based on the sampling rate of ADC inside signal converter, each magnetic field cycle contains 250 voltage readings, and two magnetic field cycles construct one measurement period which is 120 milliseconds. After one measurement successfully completed, the spikes due to change in magnetic field direction prevented by eliminating the first 9% and last 5% elements of voltage readings of each magnetic field cycle. After eliminating the spikes, moving average filter applied to remaining signal to decrease variance in voltage readings due to external noises. Finally, voltage readings refer to each of this two-cycle subtracted from each other and mean value of this difference taken in order to be used in flow calculation. This remaining potential difference between cycles, mostly caused by velocity of liquid inside the pipe, is used in flow calculation. The known potential difference may be also given by:

$$E = kBLV \tag{1}$$

Where k is the calibration constant, B is the magnetic field strength in Tesla, L is the distance between electrodes which is also equal to diameter of measurement pipe and V is the average velocity in meters per second. In this equation calibration constant k, magnetic field strength B and distance between electrodes L are constant during measurement, therefore they labeled as another k variable to be used in denominator this time and found as 8.7044×10^{-5} [V/s] during calibration process. Then, using the above formula, average velocity computed with calculated potential difference, and it is used in flow equation that is given by:

$$Q = V A \tag{1}$$

Where, Q is the flow in cubic meter per second and A is the cross-sectional area of measurement pipe in square meter. Using this equation flow calculated and flow unit converted to liters per hour by multiplying computed flow with 3600 seconds per hour and 1000 liters per cubic meter. Flowchart of measurement algorithm is shown in Fig.5.

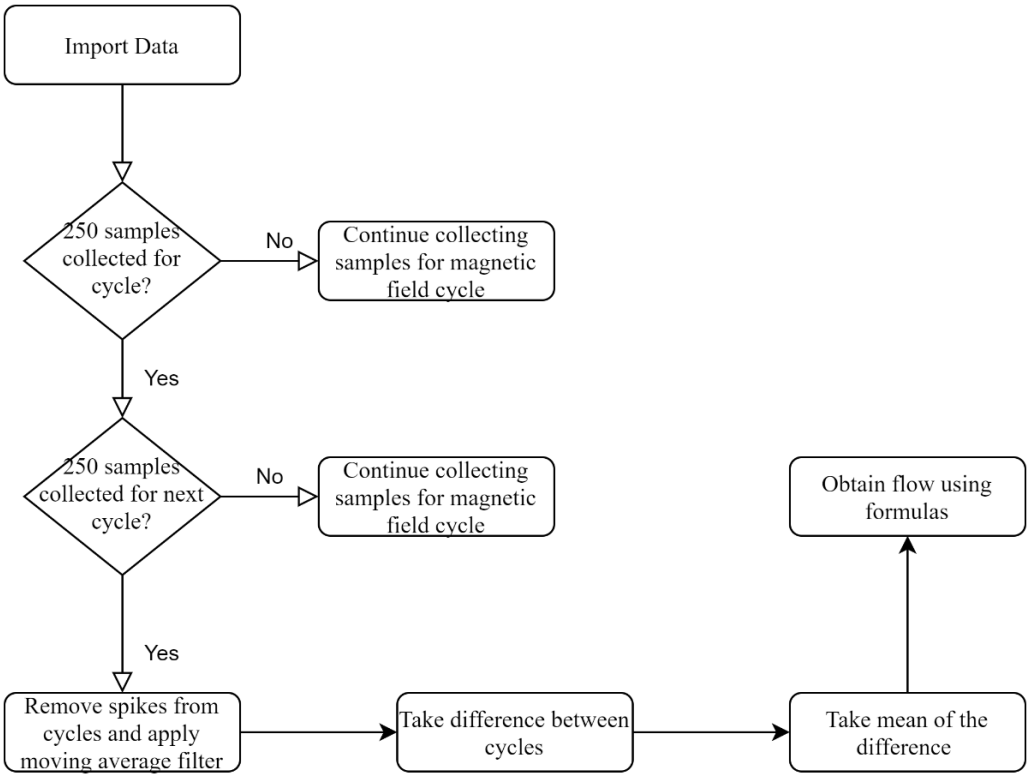

Figure 5 Flowchart of Measurement Algorithm

2.3. Proposed Electromagnetic Water Flowmeter System

Proposed system contains of three stages, sensing the induced electromotive force, preprocessing the induced signal, applying preprocessed results into embedded measurement algorithm. The block diagram of system is shown in Fig.6. The flowmeter sensor model senses the induced electromotive force due to velocity of liquid inside the pipe. The electrode pairs of sensor model forward these voltage readings to differential analog-to-digital converter of IFC 100 signal converter. Signal converter processes these data and forwards it to STM32 development board for flow computation. STM32 takes the processed analog-to-digital output from signal converter and convert them back into analog readings. This converted induced electromotive force data, then applied into the measurement algorithm that is embedded into STM32 development board and flow outputs corresponding the induced electromotive forces obtained. The block diagram of the overall system shown in Fig.6.

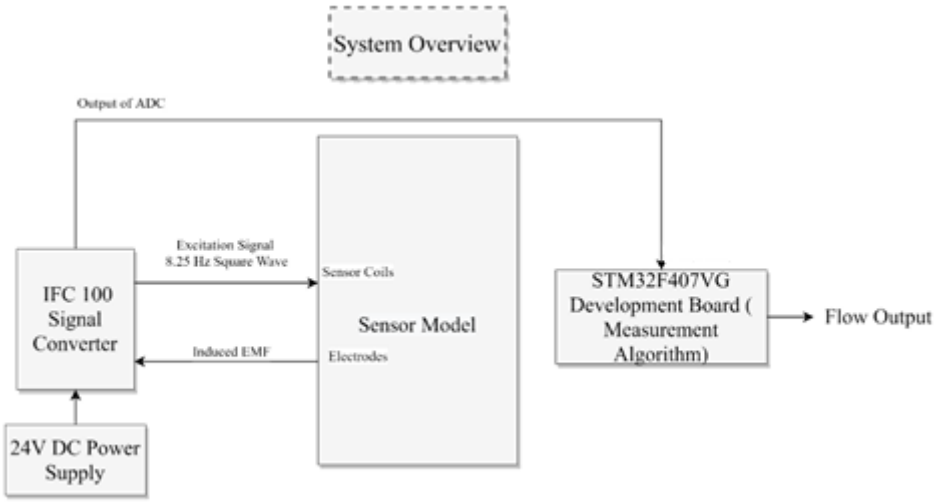

Figure 6 Block Diagram of Overall System

3. Result and Discussion

Proposed electromagnetic water flowmeter system tested on various flow levels in the range 0-3000 L/H. The voltage readings and corresponding flow results obtained during test process. The test duration per flow level is 3 seconds and each test contains 24-25 measurement periods. The sample sensor reading at flow level 2000 L/H is shown in Fig.7.

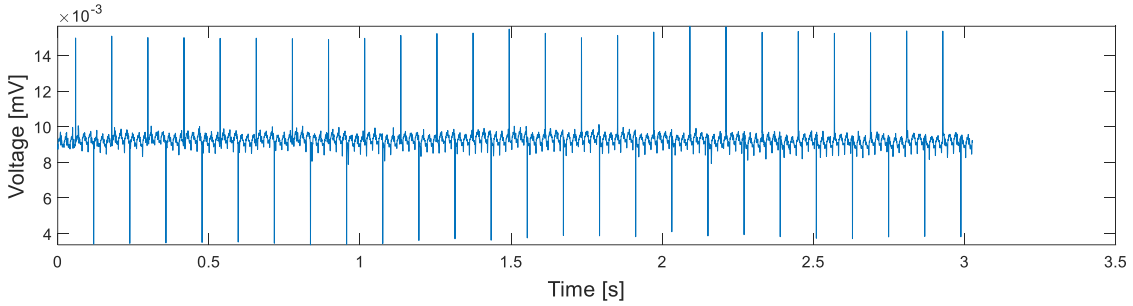

Figure 7 *Induced Electromotive force at 2000 L/H in mV*

This sensor readings indicates that there exists a spike when magnetic field direction changes. After eliminating the spikes and applying moving average filter to the measurements, the remaining signal provides useful information for flow calculation. The resultant signal after eliminating the spikes and filtering the signal can be seen in Fig.8. This figure indicates the one measurement cycle of voltage readings at flow level 2000 L/H. The signals corresponding to two different magnetic field cycles follows similar pattern but with slight difference in voltage level. This potential difference between cycles sourced by the velocity of liquid inside the measurement pipe.

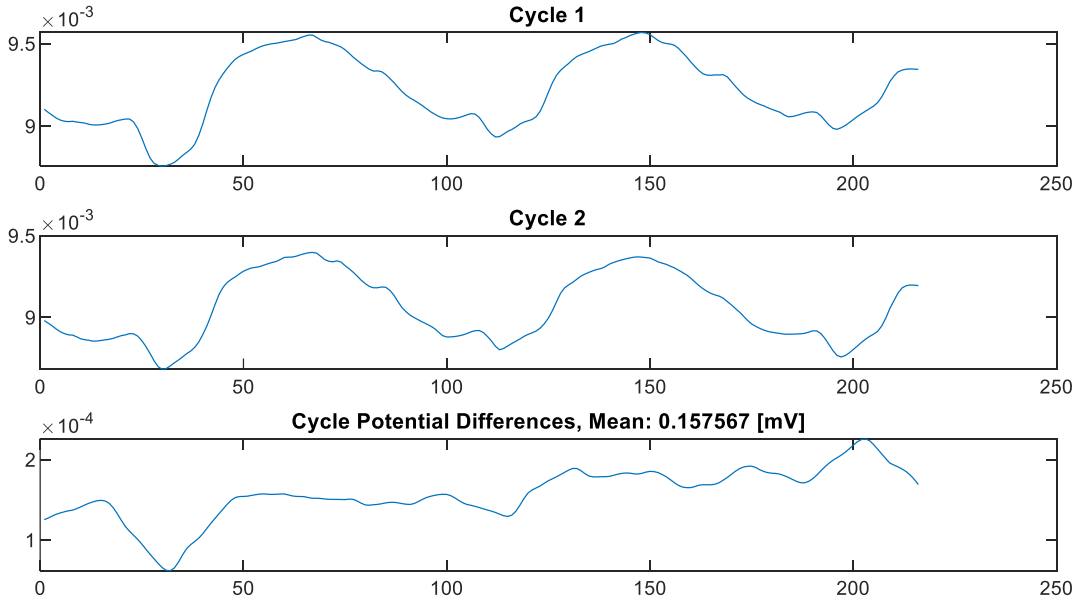

Figure 8 *Induced Electromotive force of one Measurement Cycle*

The signal lastly processed through mathematical expressions indicated from working principle from electromagnetic flowmeter. The results shown in Fig.9. The results proves that the change in flow level between magnetic field cycles directly proportional to velocity of liquid inside the pipe. This indicates that excitation signal has significant impact on output voltage waveform of flowmeter.

The results of all flow levels tested is shown in Fig.10. This figure indicates mean potential differences corresponding to flow levels. According to test results, there is a linear relationship between potential differences in cycles corresponding to excitation signal waveform and flow rate. This linear relationship can be expresses as Flow=$(1.3363)\times10^{7}\times$Voltage-26.31 which results in a 0.99 R^2 score.

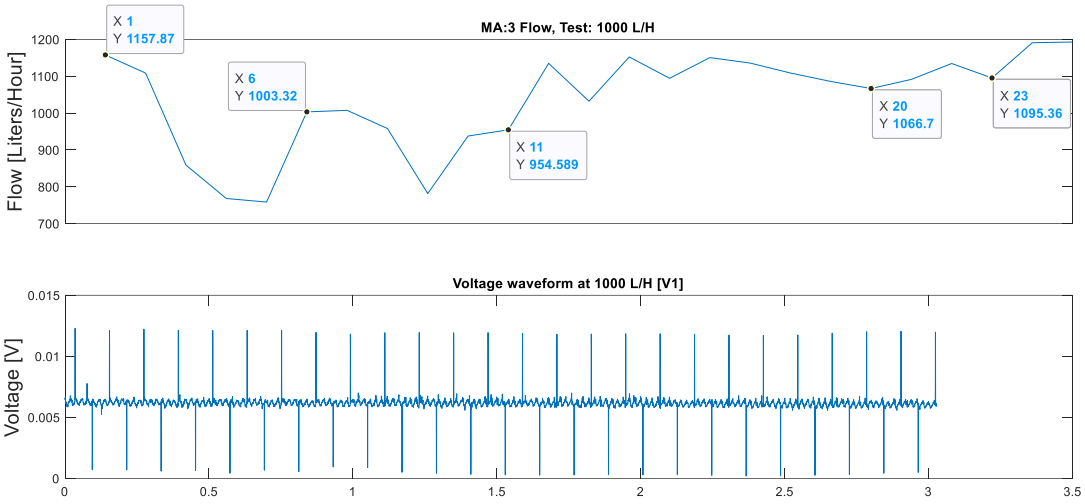

Figure 9 *Computed Flow Outputs at flow level 1000 L/H*

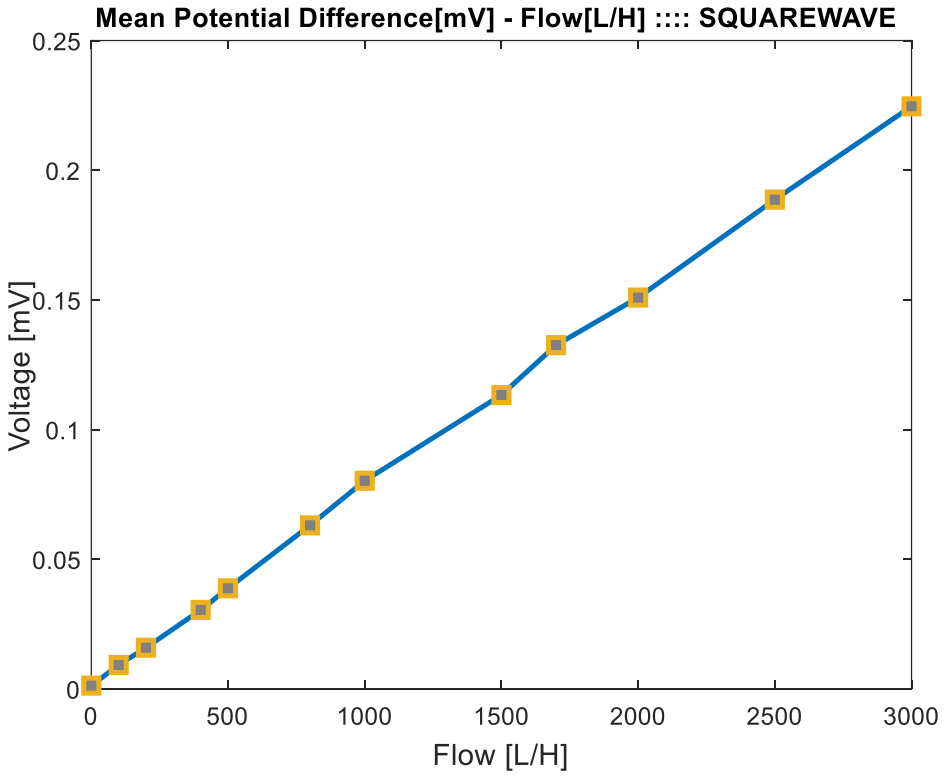

Figure 10 *Graph of Flow vs Voltage Readings*

4. Conclusion and Recommendations

In this study, electromagnetic flow measurement system design proposed based on square wave excitation signal and ARM Microcontroller. Electromagnetic flow monitoring applications require proper hardware configurations that are measurement pipe with insulator liner, non-magnetic, corrosion-free pair of electrodes, low-response times and precise calculations for flow measurements. Therefore, the requirements are proper measurement algorithm, hardware configuration and excitation signal. These requirements of this application satisfied with use of Delrin measurement pipe, 304 stainless-steel electrode pairs, implemented measurement algorithm inside STM32 development board and IFC 100 signal converter. Proposed system tested on various flow levels to prove that the system work properly on different flow levels. Results proved that proposed system successfully accomplished the water flow monitoring task. In addition, results of recorded test flow calculations of the system on various flow level indicates that there is a linear relationship between potential differences in cycles

corresponding to excitation signal waveform and flow rate which is formulated using linear regression and it accomplished 0.99 R2 score. This successive implementation of linear model indicates that the mathematical model of the system can be used in further flow measurement for double verification of flow measurement and to increase stability of flow measurement of the system. In summary, system showed that the potential differences between the cycles corresponding to magnetic field is main criteria behind the measurement algorithm. Excitation signal has significant impact on output voltage waveform of flowmeter, therefore the measurement algorithm. Signal to noise ratio drastically decreases when the flow level is very low. According to test results, there is a linear relationship between potential differences in cycles corresponding to excitation signal waveform and flow rate. In future work, proposed hardware sensor configuration of the system can be improved in order to decrease the negative effect of external noises and linear model of the system can be embedded into measurement algorithm to increase signal to noise ratio and measurement accuracy.

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3. Architecture

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Architect Perceptions of Engineered Wood Products: An Exploratory Study of Selected Countries

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Abstract:

The wood industries in Slovenia, Macedonia, and Turkey have a long tradition of producing a wide range of wood and wood-based products. Despite having a long and prosperous history, over the past two decades, the wood products sectors in these countries have faced a steady decline in profitability, the ability to add value through downstream manufacturing, and overall competitiveness.
Engineered wood products (EWPs) are structural building materials that have been used since the early 1980s as replacements for, or in conjunction with, concrete and steel. In this study, Slovenian and Macedonian architect attitudes, awareness, and preferences regarding the use of EWPs are compared. The study is based on a sample of architects using on-line surveys. The results suggest that there is a positive perception regarding the use of wood in general in all countries, with the majority of respondents believing that wood use will increase in the future. However, specific to the EWPs, differences were found in familiarity and knowledge of potential applications in timber-based construction. Results provide indicators of knowledge gaps between respondents and, conversely, where awareness and willingness to use EWPs exist. These findings can have implications for market opportunities, identifying barriers to the EWPs adoption, and content for workshops, seminars, and other outreach mechanisms for architects.

Keywords: *Engineered wood products (EWPs); Architects; Timber construction; Slovenia; Macedonia; Turkey*

1. Introduction

Wood as a construction material has many advantages, such as the fact that it is a renewable material, its application reduces CO2 emissions and it provides connection with nature, thus enables biophilic design (Ramage et al., 2017). Nowadays, there are many innovative wooden products, available on the market. However, the introduction of new products in the construction sector, is usually met with hesitation, low awareness, and high uncertainty (Malaval, 1998).

During the 2000s, an effort was put in using forest resources in order to enhance economic, environmental, social, and cultural benefits (Dargusch, 2010). At the same time, the positive influence of the wood in the modern bio economy, and the global goal for sustainable development, through increased renewable resources, has increased the demand for wood products (Toppinen et al., 2018). The wood products sector plays an important role in the building industry and economy of Europe and beyond. Therefore, wood-based products are the most preferred building materials from energy-efficient and sustainable point of view.

1.1. Engineered Wood Products (EWPs)

A new class of structural wood products has been developed in the last two decades, in order to create design solutions that are functional and environmentally friendly, due to new industrial processes. The result is a category of products broadly known as engineered wood products (EWPs). Some of these products are shown in Table 1.

A number of studies research the barriers and challenges of wood application in the buildings, especially on wood as a structural material. Cross laminated timber (CLT) has been rapidly used in Europe and Turkey as a sustainable alternative to concrete and steel constructions in commercial and multi-residential applications such as walls, floors, roofs, and other applications.

Table 1 Examples of Engineered Wood Products (EWPs)

GLT Glulam-glued laminated timber	**CLT** Cross-laminated timber	**PSL** Parallel strand lumber	**LSL** Laminated strand lumber	**LVL** Laminated veneer lumber
				
EGP Solid wood panel	**PB** Plywood	**LDF/MDF/HDF** Low/medium/high-density fiberboard	**VP** Veneered particleboard	**PB** Particleboard
				
OSB Oriented strand board	**LS** Light sandwich (honeycomb) panels	**WPC** Wood plastic composites	**TM** Thermally modified timber	**WFI** Wood fibre insulation boards
				

1.2. Study Geographical Countries

The wood sector has a very long tradition in Slovenia, Macedonia, and Turkey. To get a better picture of the importance of the forest sector in these countries, some additional information regarding relevant forestry statistics are presented in Table 2.

Unfortunately, in the last 2-3 decades, these countries have had many economic and social changes, which are reflected on the wood industry sector. In recent years, there has been an increased effort for wood application, particularly in Slovenia, in order to lower the carbon footprint (Kitek Kuzman and Sandberg, 2016).

The examples of the traditional timber Turkish houses go back to seventeenth century. Timber house construction has widespread till the first quarter of 20th century. However this tradition has scantly continued in rural areas after 1940s. Traditional timber buildings may be mainly classified into the three sections which are log houses, timber frame, and combine construction, depending on the structural systems (Oztank et al., 2008).

Table 2 Slovenia, Macedonia and Turkey – Selected Forestry Data, 2020 (Government Statistics)

Property	**Slovenia**	**Macedonia**	**Turkey**
Surface area of forested land (ha)	$1.18 \cdot 10^6$	$1.09 \cdot 10^6$	$22{,}6\ 10.^6$
Forested area (%)	62%	42%	28%
Number of naturally occurring tree species	71	319	
Growing stock (m^3)	$346{,}10 \cdot 10^6$	$75{,}94 \cdot 10^6$	$1{,}7\ .\ 10.^9$
Annual growth of growing stock (m^3forest)	$8{,}59 \cdot 10^6$	$1{,}62 \cdot 10^6$	$47.\ 10^6$
Annual harvest (m^3 forest)	$6{,}19 \cdot 10^6$	$1{,}09 \cdot 10^6$	$32\ .\ 10^6$
Hardwoods (m^3)	$3{,}35 \cdot 10^6$	-	$1{,}68\ .\ 10^6$
Softwoods (m^3)	$2{,}84 \cdot 10^6$	-	$6{,}83\ .\ 10^6$
Consumption Per Capita (m^3/y)	0,4	0,1	$22{,}1\ 10^6$

In Macedonia, wood material is often used only for small residential houses, usually located in the mountain regions, or limited to roof construction or canopies. There has been recent interest in using wood on the buildings exteriors and in the interior applications, due to demand for beautiful aesthetic appearance.

70% of timber manufactured in Turkey is used in construction, 20% is used in furniture production and 10% is used in packaging and other industries. Timber consumption per person is between 0,075-0,085 m³ (Anonymous, 2019). There are 38 construction companies in Turkey that use Turkish timber. In 2021, a national research project supported by government was successfully completed in Turkey. Within the scope of the project carried out by Marmara Forestry Research Institute, wood products obtained from native coniferous tree species "Pinus nigra" and "Abies" were approved by the European Standards Committee (CEN). With the project, it was aimed to ensure that the visual quality classes and resistance class equivalents of the building timbers obtained from the primary coniferous tree species of Turkey are included in the "TS EN 1912" and "TS EN 338" standards, which are valid all over Europe, under the name of Turkey. “Pinus nigra" and "Abies", native coniferous tree species, were approved by CEN and included in "Eurocode 5".

In general, architects in Slovenia, Macedonia and Turkey have a positive attitude to wood application, mostly because of the environmental performance, but their attitudes towards concrete, brick and steel are traditionally more favorable, due to structural integrity and fire resistance.

In this research, the level of understanding, awareness, and potential use of EWPs from the perspectives of architects in Macedonia and Slovenia, was investigated. This is an area that has not previously been researched to any significant degree.

2. The Study

2.1. Objectives

The goal of this study was to perceive architects perceptions about EWPs in order to identify communication mechanisms to increase the understanding of EWPs. This can influence positively the wood sector, increasing employment, and national economic development.

2.2. Methods

An international group of architects developed a survey questionnaire in order to conceive information about Slovenia and Macedonia. The survey questionnaire was in English. The target population included architects, with lists complied from members of professional architect societies and associations: in Slovenia the Chamber of Architecture and Spatial Planning of Slovenia; and in Macedonia, the Chamber of Certified Architects and Certified Engineers of the Republic of Macedonia.

Respondent data were collected through the on-line survey. We sent out 320 questionnaires for each country. Taking into account non-deliverables (e.g., invalid emails addresses or out-of-business firms); the response rates were 29% for Slovenia, and 28% for Macedonia. In Slovenia, the survey process took place from late November 2016 to mid- January 2017, while in Macedonia, from March to June 2017. The questionnaire was divided into three parts: general perceptions and familiarity of architects with EWPs, specifications of non-load and load-bearing systems and questions about information sources and needs of architects.

3. Results and Discussion

About 90% of all respondents in Macedonia and Slovenia work with architecture, followed by 5% of respondents working with building construction, while the remainder work in project management, interior design and structural engineering. The respondents had an average of 15-25 years of experience in Slovenia, and 5-15 years of experience in Macedonia. In Slovenia 50% of respondents were men and 50% women, while in Macedonia 38% were men and 62% women. The selected results were presented.

3.1. General perceptions and familiarity of EWPs

Respondents were asked to identify the EWPs they were most familiar with. The results are shown in Table 3. The cells that have a percentage higher than 80% are colored in orange. In general, the overall familiarity with EWPs is relatively high.

Table 3 Respondent familiarity with EWPs

	SLO		MK	
	No	Yes	No	Yes
GLT Glued-laminated timber	1	91	6	85
	1,1%	98,9%	6,6%	93,4%
CLT Cross-laminated timber	2	90	18	73
	2,2%	97,8%	19,8%	80,2%
PSL Parallel strand lumber	40	52	25	66
	43,5%	56,5%	27,5%	72,5%
LSL Laminated strand lumber	52	40	37	54
	56,5%	43,5%	40,7%	59,3%
LVL Laminated veneer lumber	6	86	23	68
	6,5%	93,5%	25,3%	74,7%
SWP Solid wood panel	3	89	6	85
	3,3%	96,7%	6,6%	93,4%
PW Plywood board	0	92	7	84
	0,0%	100,0%	7,7%	92,3%
LDF/MDF/HDF fiberboards	3	89	13	78
	3,3%	96,7%	14,3%	85,7%
VP Veneered particleboard	3	89	17	74
	3,3%	96,7%	18,7%	81,3%
PB Particleboard	6	86	18	73
	6,5%	93,5%	19,8%	80,2%
OSB Oriented strand boards	3	89	3	88
	3,3%	96,7%	3,3%	96,7%
LS Lightweight sandwich (honeycumb) panels	14	78	40	51
	15,2%	84,8%	44,0%	56,0%
WPC Wood plastic composites	6	86	28	63
	6,5%	93,5%	30,8%	69,2%
TM Thermally modified wood	3	89	9	82
	3,3%	96,7%	9,9%	90,1%
WFI Wood fibre insulation boards	9	83	31	60
	9,8%	90,2%	34,1%	65,9%

3.2. General perceptions and familiarity of EWPs

The respondents were asked to select the use of EWPs in non-load bearing systems such as roofing, windows, flooring, exterior/interior surfaces and stairs (Figure 1). In Slovenia, a high level of priority in terms of the use of EWPs was noted for roofing, exterior surfaces and interiors. In Macedonia, EWPs

were ranked with the highest rate for the interiors, followed by flooring. Use of EWPs in exterior surfaces and windows in Macedonia was low – respondents ranked them last.

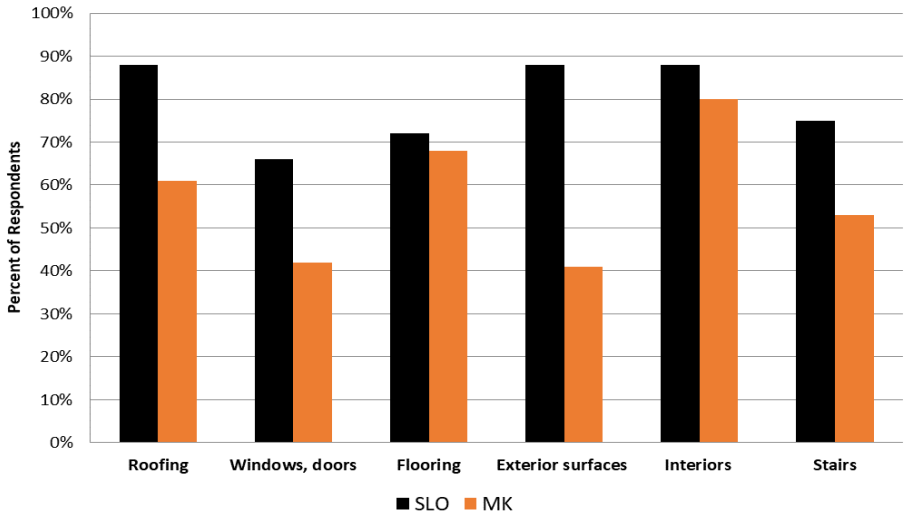

Figure 1 *Respondent specification/use of EWPs in non-load bearing systems*

Moreover, the interest in the most frequently used load-bearing systems among architects in Slovenia and Macedonia is shown on Figure 2. The results show that in Slovenia, over 60% of the respondents indicated in the first place light frame and CLT. In Macedonia the light frame was ranked first, followed by the engineering frame system. The share of log construction was quite high in Macedonia.

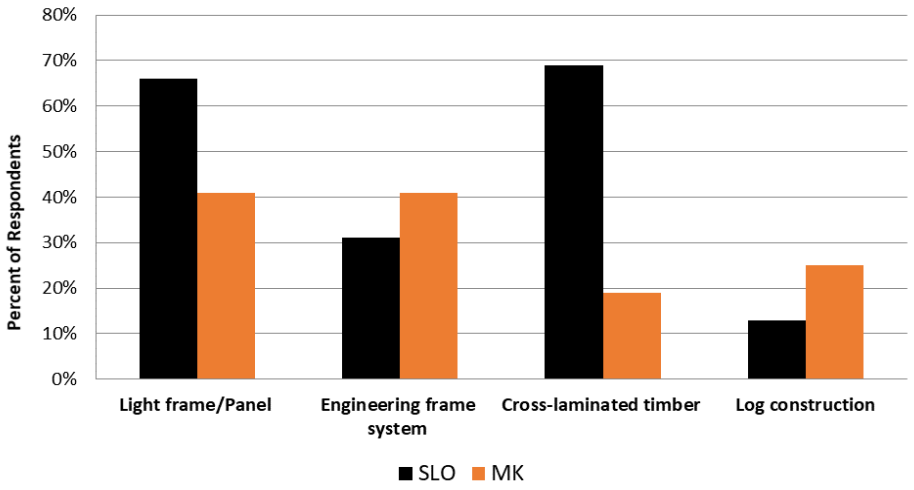

Figure 2 *Respondent specification/use of EWPs in load-bearing systems*

3.3. Information sources and needs of architects / promotional methods

Learning about products in architecture is very important and therefore respondents were asked about various methods of receiving information regarding the EWPs. The selections were made based on the following informational sources: Internet, from building companies, through EWPs manufacturers, through architect associations, and from homeowners. The respondents were asked to select a number from 1 to 3, where 1 reflected the information source was not important, while 2=somewhat important, and 3=very important. Average response values by country are shown in Figure 3. In both countries, the most important informational tool is the Internet, followed by building companies and EWPs manufacturers. In Macedonia, homeowners play an important role (ranked 4th). Architect associations are more important in Macedonia than among Slovenian architects.

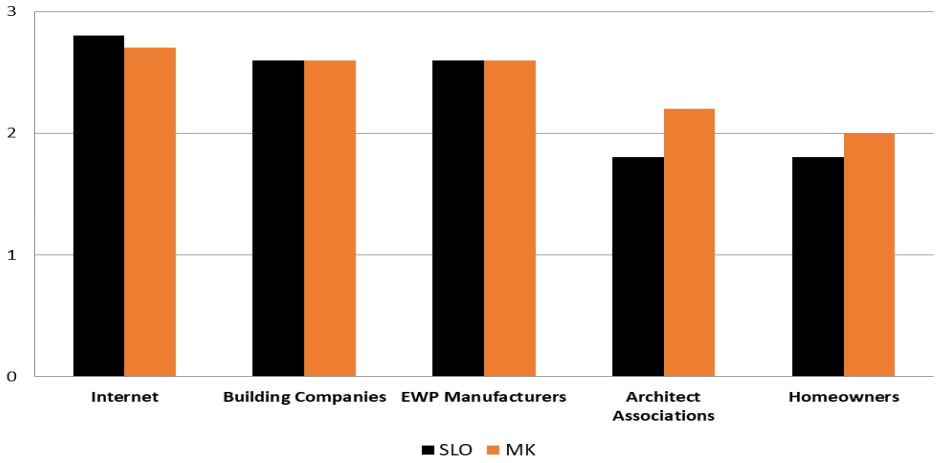

Figure 3 Respondent specification/use of EWP in load bearing systems

4. Conclusions and Discussion

The results of this study showed that there was a positive perception in terms of familiarity with different EWPs in both countries, but differences were found among respondents when selecting the 5 most familiar EWPs.

The principles in using timber for structural performance are not well known among architects. They could be good promotors of an increased use of EWPs, but their knowledge must be expanded, through demonstration projects, collaboration among representatives of the wood industry, architects, builders and housing associations, in order to achieve better understanding of the potential of wood. A more diverse group should be targeted in this region, e.g. including contractors and civil engineers. Moreover, it is important to have technical specifications and also experience to ensure understanding of the performance of bio-materials in buildings, from design, to construction, to use. The change is always difficult and the barriers to wood are complex, but with the right focus, the wood industry can make a difference. EWPs application can create new business opportunities. In addition, the authors believe that the EWPs can be an important element of a more sustainable future built environment, but more information about use and perceptions is needed.

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Digitalisation in Wood Design

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Abstract:

As a result of the potential of computing, parametric design and digital manufacture, it is now possible to design structural wood elements and wooden structures that deviate from orthogonal practice and form complex shapes. Digitized processes have also entered other industries, which are related to buildings construction and changed the way they work, as well as finished products. Architects, designers and engineers are provided with powerful analytical tools to create new designs for wood products, predict their behavior, and formulate effective production strategies.

Innovative techniques of representation and technologies in architectural design intend to undertake the digital representation strategies that can change the future of wooden architecture through the combination of tradition and innovation. Engineered wood products offer greater design freedom for ambitious construction and manufacture technology.

The purpose of this article is to define different interpretations of organic architecture, to find the respective most influential representatives, as well as to present the key laws that influenced architectural design and planning.

Keywords: *Digitalization; Wood design; Timber constructions; Future; Innovations; Architecture*

1. Introduction

Just two decades ago, computers in architectural offices were mostly used in writing texts, accounting and bill of quantities calculations. At the turn of the millennium, however, these offices were updated with different equipment: computers, scanners, printers and software such as AutoCad, ArchiCad, 3dsMax, Maya, Rhino, Sketch Up etc. Today it is not possible to find architectural office without digital technology. The question is not whether this is good or bad, but what is the direction that architecture is taking, under its influence (Picon, 2010). We are faced with many technological innovation, and the changes they bring, have a major influence on the architectural design.

The development of digital architecture was undoubtedly due to the desire for shapes that were impossible to design with existing tools. By the early 1990s, sophisticated geometric design was presented with paraboloid and hyperboloid shapes, such as concrete shells, tensile structures or smooth and loosely defined shapes of molded plastic or pneumatic structures. The increasing use of computers has changed sophisticated geometric design. Digital architects have dramatically increased the vocabulary of shapes. Novelty is not only the diversity of the shapes themselves, but also the ability to specify these shapes using computer modeling (Bianconi et al., 2019).

Digital architecture has revived the imitation of shapes from nature. Architectural shapes have historically been based on geometric lines present in nature. These shapes were inspiration for simple designs of the first civilizations. A circle, an ellipse, a triangle, and a rectangle are combined into harmonic proportions (e.g., golden ratio), which generated a logarithmic spiral (Hemenway, 2008). The spiral shapes can be seen in the volutes of ionic columns. A modern interpretation of this concept is the Turning Torso Tower - a skyscraper built in Malmö, Sweden (Figure 1). The Etruscans developed an arch and vault of basic geometric shapes, while the Romans upgraded this development with a dome. Gothic architecture took over Greek geometry and added Celtic to its imitation of forms from nature. The Renaissance founded architecture as a new science, demanding that every part of the building should be integrated into one of the systems of mathematical relations - a rule that is a precursor to the mathematical laws included in digital design and engineering tools.

Figure 1 Turning Torso Tower, Malmö, Sweden (amazing-places1.blogspot.com)

With the implementation of the digital tools, the concept of organic forms is returning to architecture. It first appeared in the early 20th century, derived from the ideas of Viollet-le-Duc and John Ruskin. Wright complemented their ideas with Sullivan's axiom "form follows function" and developed an organic architecture that delicately incorporates nature into the design of the building and blends in perfectly with it (Wright, 1963). Gaudi studied static forces in nature. The pillars in his architecture are often inspired by the thick trees that nature has optimized through evolution. Organic architecture seeks inspiration in nature, also by imitating the forms of living organisms. These have evolved in response to external influences. For example, the shape of the Eiffel Tower was inspired by the human femur. Biomimicry is also an integral part of architectural planning in the 21st century. Norman Foster found the shape of the Gherkin Tower in London (2003) in sea cucumber (Figure 2), which with its round shape resists strong water currents in the depths of the sea (Benyus, 2008).

Figure 2 *Gherkin Tower in London, inspired by the natural shape of sea cucumber (thegherkinlondon.com)*

Wood is coming back in architecture, this time in a high-tech design, in the form of massive elements and composites. In design and construction demanding projects, some materials competing with wood may have certain technical advantages, but their energy and ecological balance, as determined by the amount of gray energy of materials and product life cycle assessment, is dramatically worse than wood (Torelli, 2009). With modern technologies of wood disintegration and reintegration, it is possible to eliminate natural "defects" and thus optimize wood properties in the form of wood products. It is very successful to add value with innovative design.
In this paper, we discuss the digitization of processes in architecture from design to execution of wooden structures. Digitally supported design and fabrication technology has revealed new potential for realizing complex shapes with sustainable materials.

2. Digital Tools for Virtual Design

Over the last decade and a half, new tools have offered the opportunity to experiment with different organic forms in architectural design. Digitization of processes introduces the concept of "digital architecture". In the processes of creating a built environment, various digitized processes are used, in which physical forms are created with the help of virtual forms. Computer tools have not only replaced classical drawing tools, but also represent an upgrade to the recently known drawing techniques and enable the design of shapes that were impossible to draw with existing tools. Digitization in the processes of architectural planning has brought the possibilities of design with the synergy of forms from nature (biomimetic, biomimicry), intuition, mathematics and geometry. The most direct consequence of the use of computer tools is undoubtedly the possibility of manipulating the complex geometry, which allows the control of bent surfaces.

2.1. Digital architecture

Digital architecture is created through computer modeling, programming, simulations and imaging and creating virtual and physical forms. This can be done by complex calculations, using powerful computer algorithms, which offer a variety of complex forms (Fischer, 2012). CAD programs can be upgraded with a variety of digital tools to generate curves and three-dimensional surfaces. Realistic experiments in the form of models and mock-ups are no longer needed in the design process, they are replaced by simulations and modeling. In the early design phase, they enable accurate visualization and replace prototypes or mock-ups that were sometimes used to experiment with shapes and check the adequacy of the design. The DMU (Digital MockUp) tool, originally used in the design of cars and airplanes, was

first used in architecture by Frank Gehry for the Guggenheim Museum in Bilbao (1997) (Szalapaj, 2005). The NURBS (Non Uniform Rational Basis Splines) tool was used to build the Modern Museum in Graz (Peter Cook and Colin Fournier, 2003) (Figure 3). Only with an algorithmic design process was possible to create a roof over the courtyard of the British Museum in London, designed by Foster & Partners and the facilities for the 2008 Beijing Olympics, Aquatics Center Water Cube, PTW Architects (National Stadium Bird's Nest, Herzog & de Meuron) (Patrick, Zou, Leslie-Carter, 2010).

Figure 3 Modern Museum in Graz (photo: Marija Miloshevska Janakieska)

2.2. Digital wood design

Digitization of the planning process is also included in the wood industry and wooden structures. The so-called "digital wood design" is characterized by innovative techniques used in architecture that enable a high level of prefabrication and ensure the greatest possible freedom in architectural design with the highest quality of wooden construction (Bianconi et al., 2019). The future of sustainably designed wooden architectural structures is a combination of visible wood, digital design and advanced machining technologies.

Wood is a natural composite and has been used throughout history as a durable construction material. Renewable wood is an ecologically healthy raw material, but only if its extraction, processing and use are sustainable (Torelli, 2009). Modern, design-ambitious architectural constructions today demand even greater spans from the material with minimal diameters of load-bearing elements and shapes that solid wood does not allow. The wood industry is developing a number of new wood-based engineering products that maintain the sustainable character and physical properties of this natural material, while following trends in organic forms that sometimes even defy the laws of gravity. Appropriate methods of processing and treatment of wood products can reduce or completely eliminate unwanted defects in solid wood, while using basic engineering principles to improve its properties and adapt the construction, cross section and shape of such a composite to the intended use (Kuzman et .al., 2018) (Figure 4). Wood and wood engineering materials, including glued laminated wood, cross-laminated wood, PSL, LSL and LVL products, solid wood, veneer plywood, various fiberboards, veneer panels, chipboard, OSB board, lightweight panel composites, wood-elastic composites, modified wood, wood fiber insulation boards, etc. are an ideal material for building complex construction forms with digitally supported design and fabrication technology (Sandberg et al., 2018).

After the planning phase, the digitized processes continue in the implementation phases. Modern wooden constructions are also created in the processes of digital design and production. These processes use computer-aided design - CAE (Computer-Aided Engineering), computer-aided design - CAD (Computer Aded Design) and computer-aided manufacturing - CAM (Computer-Aided Manufacturing) (Neubau Swatch Biel, 2019). Today, manufacturers cover all phases in the entire construction process:

from technical development to construction, use and maintenance. Flexible design tools and CNC processes (Computer Numerically Controlled) allow the design and construction of advanced wooden architectural structures of new dimensions and shapes. The framework for the manufacture of components consists of mathematically accurate parameterized models of the structure and its components, which ensure that the deviations in the phases of manufacture, processing and installation are as small as possible.

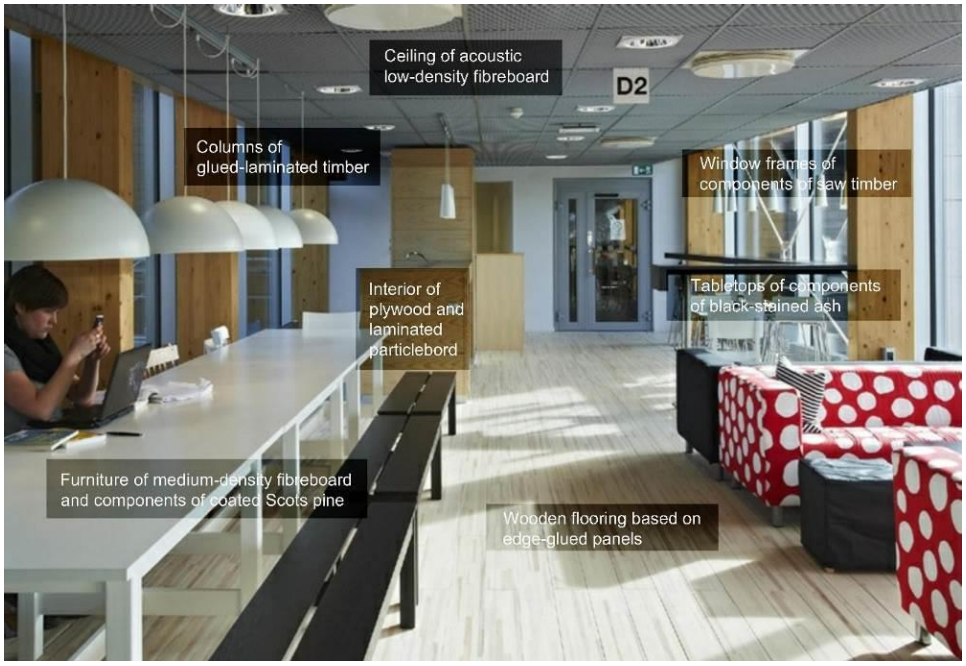


Figure 4 *Use of engineered wood materials in the room, House N at Linnaeus University (Educational building), Växjö, Sweden, 2011 (Kuzman, Zbašnik-Senegačnik, 2019)*

2.3. Possibilities of using wood in additive technologies - 3D printing with wood

Digital processes in production have led to the development of additive technologies or conversational 3D printing technology. 3D printers, which were originally used to make models in small dimensions, have evolved to sizes that allow printing of larger structural elements and structures. Being environmentally friendly and affordable, at the same time, wood materials are being developed for 3D printing, enabling different printing methods (stereolithography, inkjet powder printing / droplet application / binder spraying, cutting of cut layers, layering modeling (FDM) and extrusion - material injection). Special emphasis is placed on the development of materials derived from natural raw materials, which would be cheaper and free of harmful substances during the manufacturing process, with the possibility of using waste raw materials and recycling after use. Wood or wood residues are one of the raw materials that will be used for 3D printing in combination with natural and synthetic polymers in architecture (Karič et al., 2017).

Among the various 3D techniques, wood is most useful in the FDM (Fused Deposition Modeling) technique (Tao et al., 2017), which is also suitable for printing larger products with appropriate equipment. There are filaments on the market from different manufacturers with different proportions of wood. Wood is a filler, it is mixed with a thermoplastic polymer in the filament manufacturing phase. The filaments contain mostly up to 40% wood (Table 1), larger proportions already represent the possibility of nozzle clogging, and molten polymers with a higher proportion have too high a viscosity for extrusion on existing 3D printers. Filaments with a higher proportion of wood are more brittle.

To date, the initial models of 3D printers, which enabled the production of small prototypes, have been joined by techniques that can be used to build models the size of a house. Shapes are not limited to orthogonal lines, as 3D printers also allow the execution of very complex organic shapes in very high resolution, surface quality and use a wide variety of durable materials. The prototype 3D printed wall

was designed and engineered at the Institute for Advanced Architecture of Catalonia and was carried out by Crane WASP as part of the Open Thesis Fabrication research program, which focused on the production of construction additives.

Table 1 *Appearance of the surface of the product printed with filaments with different proportions of wood. (20x magnification, photo Jure Žigon) (Kuzman Kitek , Zbašnik-Senegačnik, 2019)*

					
Percentage of wood in the filament - 0%	Percentage of wood in the filament - 10%	Percentage of wood in the filament - 20%	Percentage of wood in the filament - 30%	Percentage of wood in the filament - 40%	Percentage of wood in the filament - 50%

3. Materialization of the Digital Model with Digital Processes and Sustainable Materials – Wood

Complex building shapes are much easier to achieve with modern tools. The list of materials has also expanded – besides originally used concrete, metal bars and plastic, wood in various forms is also applicable (from solid construction, wood composites to 3D printing).

Today, wooden constructions take on organic forms and co-create organic architecture, such as Kilden Performing Arts Center (Norway, 2012, ALA Architects and SMS Architects) (Kilden / ALA Architects, 2019) Figure 5a, Metropol Parasol (Spain, 2011, Jürgen Mayer) (Metropol Parasol / J. Mayer H + Arup, 2019) Figure 5b, House of bread (Austria, 2017, Coop Himmelb (l) au) (House of Bread, 2019) Figure 5c and La Seine Musicale (France, 2017, Shigeru Ban and Jean de Gastines) (La Seine Musicale / Shigeru Ban Architects, 2019) Figure 5d. They stand side by side with the traditional buildings, which requires a digitized implementation process, where all components are quickly, flexibly and accurately designed and executed with digital processes in workshops. Checking the design with 3D models, the possibility of static assessment of the structure, solving technical problems in production, assembling parts or the entire structure on the construction site results in rapid construction of the building on site and a small number of finishing works.

a b c d

Figure 5 *Wooden constructions with organic forms: a. Kilden Performing Arts Center, Norway [https://en.wikipedia.org/wiki/Kilden_Performing_Arts_Centre]; b. Metropol Parasol, Spain [https://en.wikiarquitectura.com/building/metropol-parasol/]; c. House of bread, Austria [https://www.inexhibit.com/case-studies/asten-austria-the-house-of-bread-by-coop-himmelblau/]; d. La Seine Musicale, France [https://www.laseinemusicale.com/]*

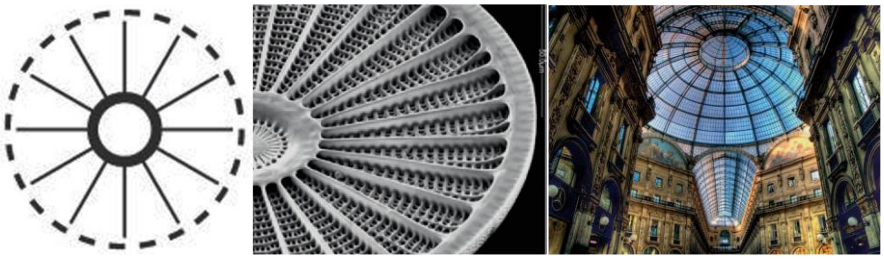
Besides digital processes for development of the organic architecture, modern architects sometimes include traditional techniques, such as origami, applied to different dynamic paneling shapes for various purposes, e.g. acoustic performance control, stability and load bearing capacity of the building etc. (Figure 6). Different patterns can be tested through digital simulation and, at the same time, paper folding. One of the main advantages relies on the possibility to perform variations: the resulting

geometry can be obtained in real-time, allowing a dynamic and interactive optimization process (Lo Turco et al.).

Figure 6 *Different solution of rigid cardboard to stimulate its rigid-foldability (Lo Turco et al.)*

Organic architecture seeks inspiration in nature also by imitating the forms of living organisms. Diatom frustules are inspiring for various shapes in architecture and industrial design. Diatoms constitute a highly diverse group of unicellular, photosynthesizing eukaryotes that are common in marine and freshwater habitats and represent an interesting inspiration for buildings.

The radially organized ribs in radial centric valves (Figure 7a) are in some species reinforced by concentric ribs perpendicular to the radial ones, as shown in Arachnoidiscus (Figure 7b). This pattern of ribs resembles the reinforcement structures of large domes. Examples are the glass domes over the Reichstag building in Berlin, Germany, and the Galleria Vittorio Emmanuele in Milan, Italy (Figure 7c) (Kooistra and Pohl, 2015).



a b c

Figure 7 *Schematic organization of a valve of a centric diatom in valve view; b. Scanning electron micrograph of the inside of a valve of the radial centric diatom Arachnoidiscusc. c. The central dome of Galleria Vittorio Emmanuele at Milan, Italy; an example of a glass dome supported by a structure of radial and concentric ribs structurally and functionally similar to that in the valve of the radial centric diatom Arachnoidiscus. 10. (Kooistra and Pohl, 2015)*

In addition, organic shaped experimental pavilion made of fibre glass reinforced plastics (GRP) was designed after detailed study as an organic form which mimics the ge¬ometric pore structure of marine diatoms. The structure should inherit their positive structural properties. For this pavilion (Figure 8), glass fibre reinforced plastic (GRP) was selected as the construction material as it is particularly suitable with light weight, has high compressive and tensile strength and, most importantly, can be shaped with flexibility. The outcome shows that through the clever use of parameterization, entire design and architectural production processes can be adapted and reduced to a set of different families of forms that combine the same basic characteristics. [Optimizing Digital Organic Freeform Modelling for Fabrication by Using Parameterization With Glass Fibre Reinforced Plastics (GRP); A case study; Jan-Ruben Fischer].

A Timber Wave prototype was constructed at the University of British Columbia Campus, as a product of digital design (Figure 9). The aesthetic of the prototype is stunning, due to the waved shape, which also contributes to its structural stability.

We anticipate that in the development of additive technologies using wood, the range of their use in the construction field will expand, especially in the construction of prefabricated houses and for the production of more complex products adapted to the individual with a higher level of functionality and design surplus.

Figure 8 *Photo of the finished pavilion (Fischer, 2012)*

Figure 9 *Wooden structures as a product of digital design and implementation: Timber Wave prototype, doubly curved timber assembly, at the University of British Columbia Campus (Correa et al., 2019)*

4. Discussion and Conclusions

The approach in architectural design has changed with digitization; objects are no longer designed, but calculated (Bianconi et al., 2019), which allows the implementation of complex shapes, that would be difficult to represent using traditional drawing methods. The coordination of the various steps, such as architectural design based on geometric structures, structural engineering, production, logistics, site facilities, installation and follow-up work, is a core element of contemporary project management.

In architecture, the trend of designing with organic, non-orthogonal lines has begun to re-emerge and was enabled by modern digital tools. Organic forms, which in the past only the greatest minds (such as architects Gaudi, Wright, Fuller) were able to bring from the conceptual to the implementation phase, are today more easily accessible with the support of computers and parametric tools. In this forms are hidden all the concepts that have been developed in history. Digitization in architecture brings design possibilities with the synergy of nature, mathematics, geometry, intuition, and so on.

The tendencies to inspire forms and processes in nature are also more intense. Although nature cannot be directly copied, architects and engineers can be inspired by the living world for their creative designs by analyzing physical subjects. On the other hand, connecting the built environment with nature - with views of nature, the use of natural materials (especially local materials) and taking into account local ecology in planning construction and use - should improve the user's perception of the natural environment and increase motivation for greater care for the environment. REED is a building design paradigm expanded from restorative environmental design (RED) and regenerative design to include aspects of ergonomics and kinesiology, as well as a scientific support framework. The relationship between nature and the built environment are critically important to both RED and regenerative design (and, by extension, REED). RED and regenerative design focus on the relationship between people and the environment at individual and societal levels in order to maximize the benefit for all. The basic goals of these paradigms are to both minimize harm and provide positive benefits to nature, people, and societies. To do so, the relationship between nature and people, referred to as biophilia, is leveraged by connecting building users with nature to provide positive health benefits for users and invoke a sense of connection to the environment that causes them to care for it.

Digital design and modern production technologies characterize wood as the optimal material. For this purpose, in addition to solid sawn wood, many engineered wood products which have good mechanical properties, are aesthetically pleasing, attractive in appearance and highly functional, have been developed. Wood and wood composites offer the ability to build with sustainable, fully renewable and high-performance material from both an energy and construction point of view. Together with architectural solutions of organic forms, wood is a valuable alternative to materials that until recently served as architectural articulation (Bianconi, 2019). In addition, a sustainable contribution to the choice of materials is becoming crucial. Cascading use of wood is the smart way to use a natural resource – putting it to good use before it is reused, recycled and finally burnt for energy.

3D printing with natural raw materials is also expanding into the field of non-standard architecture of organic forms. 3D printing and digital manufacturing is one of the futures of design. It would also make sense to invest in further research of 3D printing with natural raw materials with an emphasis on wood biomass and technologies, where the use of wood particles is possible.

The development of potential modern wooden structures, which are a combination of tradition and innovation, is seen in the observance of biomimetic principles in architecture and engineering design, in the connection of digital design and fabrication of structural elements using numerically controlled machines. Engineers know digital tools, have the ability to geometric representation and design knowledge, while architects have ambitious ideas for specific building shapes made possible by the digitization of processes.

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ICT Usage Among Syrian Refugees to Improve Connectivity

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Abstract:

Substantial changes occurred after the adoption of modern technologies of Information Communication Technology (ICT) in everyday life. These electronic technologies have surpassed most institutions such as e-governance, e-democracy, e-learning, e-health, e- culture, e-tourism aimed to provide services for all human beings (Diminescu et al., 2011). Nowadays, with having digital tools and comprehensive telecommunication technologies, people can connect virtually. It became an essential need for every individual especially for refugees and displaced migrants. Moreover, implementing ICTs in refugees‟ camps would create a new body of knowledge, methods and process.

Across the board, Turkey has been listed as one of most countries including significant number of refugees, war-affected and marginalized people over the past years. In this paper we are going to put the light on the role of connectivity for refugees during their displacement. We are going to give examples and related study regarding ICT role among refugees, specifically Syrians located in Turkey.

Keywords: *Information Communication System (ICT); Refugees Camps; Social technologies; Digital literacy; GIS*

1. ICTs among Migrants and Displaced Refugees

The journey starts when groups of people forced to flee regarding a conflict in their home country. Since there is not any recognition of the destination, searching for information is needed. These groups who are called migrants, start to look up for a way to guide them during their journey. Perhaps we should distinguish between the term "refugees" and "asylum-seekers". According to UN law, "refugees" are the ones who have been granted refugee status and asylum seekers are the ones who have applied for asylum and are still in agreement. (Dekker et al., 2018). Connectivity a method where all migrants whether they are refugees or asylum seekers are virtually connected to a resource to check for information and connect to others. Connectivity is facilitated by technology and digital tools including ICT that stands for Information Communication Technology. It is a term of using computer and smartphone. ICT plays an important role for refugees to communicate and to navigate their locations and follow routes using applications along with Internet connection services (Tossell, 2017).

It was hard to imagine how the phenomenon of digital communication would become. For the time being, communication via multiple social applications as emails, Facebook, Twitter, LinkedIn, etc., have been consumed exceedingly. According to UNHCR, refugees keep tracking of Facebook, Skype, Viber, and WhatsApp to find information and communicate (UN, 2016). Various resources mentioned the significant implementation of digital application for many migrants and displaced persons even for trivial details. For instance, e- Diaspora is an electronic website delivered to migrants aims to promote digital communication. It has been used to collect data and analyzes immigrants from Nablus, China, Morocco, France, and others (Diminescu et al., 2011). This application aims to collect and categorize data and maps to serve migrants and to deliver the correct data as much as possible. This application was supported by more than 80 international investigators where about 8,000 immigrant web sites have been collected and monitored in interactional way.

Wilding in his paper described the ability of ICT in connecting people over the seas. He showed distinguished between families who like to make chats in one room with all members across the globe and other who prefer to communicate individually (Wilding, 2006). The research found that most widely used ICT tools is email because is not limited on time zones or specific users. E-mail has continued to improve social communication and strengthen family ties among refugees regardless of the place and vast distance. It is widely available for Australia, Canada, and similar developed country.

1.1. Digital Refugees

In fact, technology allowed people to construct a digital roundabout way to access information and connection with their relatives and friends. An example is included in an article done by Schejter and Tirosh which mentioned some African refugees who built up a social network to access information, media and contact with relatives and friends. They got their own network, social media platforms connected to the main local server (Schejter and Tirosh, 2017). Moreover, in the paper of “The Best, The Worst and The Hardest to Find: How People, Mobiles, and Social Media Connect Migrants in (to) Europe” there is a description of a system called Schengen Information System (SIS) is used to collect information regarding travel routes and destination of the displaced people (Borkert, Fisher and Yafi, 2018). The study examined the pleasure desirable consequences of mobile technology among users comparing to the line-based communication tools such as telephones. In general, information is provided through an accessible solution for refugees because of their free availability, accessibility, and long-range communication.

Distinguished from other technologies, Transnational mobility is a term defined to enable mobile users staying connected, take advises about new locations, socialize with other migrants, newcomers and communicate with their beloved ones back home (Wall, Otis Campbell and Janbek, 2017). Transnationalism identified as extending or going beyond national boundaries through technology. However, after mentioning those examples of ICT tools among refugees, it is a must to put a long systematic plan. This plan is put into service for refugees and measure the information accuracy to not be subjected to theft or cruel treatment.

1.2. Communication Security Awareness

Communication is not less important than food or health care. The UNHCR stated the precents of refugees who relate to Internet. Although 29 percent of refugees do not have the access of Internet nor mobile coverage, lots of them spend third of their financial assistance on Internet to connect with their relatives and friends (UN, 2016). One of the important pillars to survive is connecting with relatives and friends. Locating in rural areas is also a challenge for refugees. It is hard to implement mobile connectivity of 2G and 3G in such rural areas. In the same line, there are other reasons that obstructs implementation of ICT tools among refugees and camps. Law connectivity in rural or camp areas, analphabetism of some refugees and high cost of calling cards are further means of connectivity limitation (Schejter and Tirosh, 2017). Limitation of these technologies are the inability to connect via other local networks and could cause political problems if they are linked to a suspicious network (Leung, 1390).

A research of "Syrian Refugees and the Digital Passage to Europe: Smartphone Infrastructure and Affordances" indicated the number of mobile users in Arab states. It examined the methods of refugees using digital tools to show them the way of their journeys and the pros and cons for the forced migration (Gillespie, Osseiran and Cheesman, 2018). Not all information on social networking sites is imperative and reliable. There are sources that may not look real or have political backgrounds that may violate their security. Perhaps the best networks available to support immigrants are the networks of international and governmental organizations that work to include information and provide them to immigrant refugees (Dekker et al., 2018). Refugee migrants are more vulnerable to exploitation through those digital platforms that may hinder or endanger them. Moreover, refugees through sharing and posting information on social media applications could be vulnerable to some behaviors of aggression that causes harm.

2. Refugees' Issues, Camps Conditions and Communication Need

In the agreement of the United Nations Refugee Agency, 182,621 Syrian refugees were living in Turkey from 2013. The number has increased in the following years due to the progressive number of Syrians fleeing from the conflict. Fairly close to correct, 10% of the displaced individuals have stayed at the refugee camps depending on the statistics of Ministry of Interior Directorate General of Migration Management (Çetinkaya et al., 2016). The camps were distributed in the western southern side of Turkey mainly in territories of Gaziantep, Kills, Islahiye, Hatay and Istanbul. The camps were designed as containers or tents. The report of "Syrian Refugees in Turkey" indicated the number of Syrian individuals outside the camp is higher. UNHCR assisted with Accenture Development Partnerships (ADP) (UN, 2016) highlighted the following points for the purpose of developing refugees" connectivity and Internet usage:

1. The availability of connectivity for refugees staying in populated areas is wider comparing to the outside cities. The difference is mainly referring to the type of networks which are 2G and 3G.
2. The approachable of Internet is limited by the services cost. There is an empty space between the number of refugees who own mobile phones and who are not. Many refugees do not have cellphones and approximately one member of every family would have a shared mobile phone for all members. Some of host countries put regulations on refugees preventing them from working or moving around the area like other inhabitants.
3. Number of mobile phones possessed by refugees varies from site to site. For example, UNHCR mentioned that refugees who are in bigger cities own mobile phones more that the smaller areas.
4. Measurements of digital knowledge and lack of foreign languages of refugees considered being an obstacle for connectivity. It is a double-edged issue that some refugees may have

basic information of using digital tools but without English knowledge to deal with those tools and vice versa.

5. An affordable solution for providing accessibility to the Internet is the Mobile broadband and stable-line broadband that has wider range of services in public spaces.
6. Refugees have noticeable worth to sustain connected.

2.1. Syrian Refugees in Turkey

An organized rebellion against authorities conducted by people from Middle East shaped a noticeable change of people's locations. After the conflict in Syria, Syrians became vulnerable in the mean of humanitarian conditions. Many reasons were behind this crisis. The security situation in Syria between 2011 and 2012 was the biggest factor in the Syrian emigration. The Syrians who fled their country to the surrounding geographical cities. Most of them were distributed in Turkey, Lebanon, and Jordan as well as European countries especially Germany and Sweden (Seeberg, 2013).

The number of Syrians in Turkish territories exceed 2.7 million refugees distributed in urban areas and camps (Baban, 2017). To meet the emergency, the Turkish government provided accommodations and basic needs for more than 100000 refugees fled their country in the beginning. Apparently, the number increase as Turkey was a preferable destination especially for Syrian's inhabitants coming from Idlib, Latakia, Azaz and northern Aleppo. Starting with 8 camps in early September 2011 with 8000 registered refugees and then the number extended to 15 camps hosting 156,000 registered refugees. Those camps were 13 tent cities and 2-container camp in 7 border territories (ÖZDEN, 2013). Looking at latest figures of the Turkish Disaster and Emergency Management Presidency, the placement and current amount of the camps is presented in Table 1.

Table 1 Numbers of Syrian refugees in camps in various provinces, mid-January 2013 (ÖZDEN, 2013)

Refugee Camp	Province	No. of tents / containers	No. of refugees
Yayladağı-1	Hatay	2,074 tents - 259 divisions	12,708
Yayladağı-2	Hatay	2,074 tents - 259 divisions	3,239
Apaydin	Hatay	2,074 tents - 259 divisions	3,345
Altinözü Tekel	Hatay	2,074 tents - 259 divisions	1,212
Altinözü Boynuyogun	Hatay	2,074 tents - 259 divisions	1,622
Reyhanli Reception Center	Hatay	2,074 tents - 259 divisions	N/A
Akcakale	Sanliurfa	4,829 tents	16,735
Ceylanpinar	Sanliurfa	4,767 tents	20,836
Kilis Oncupinar	Kilis	2,053 containers	13,074
Islahiye	Gaziantep	1,743 tents	8,360
Karkamis	Gaziantep	1,588 tents	6,235
Nizip	Gaziantep	1,580 tents	7,493
Osmaniye	Osmaniye	2,012 tents	8,228
Kahramanmaras	Kahramanmaras	2,300 tents	15,137
Adiyaman	Adiyaman	2,000 tents	5,993

Refugees who arrived in Turkey were given ID card and placed in temporary places such as camps and tent. They were supplied with essential needs and provided with free health care. Despite the mentioned needs and safe place given to refugees, conditions of the camps are sometimes problematic. Groups of refugees expressed discontent of the condition of the camps whether the place itself or the services provided. In this way, other fundamental equipment should be taken into consideration to raise the services provided in camps.

2.2. ICT Endeavors in (Digital) Refuges' Camps

A resource called "Indigenous Schemes‟ mentioned a way to support the refugee camps with constraint communication services. In this way every single person will be able to use a shared mobile phone with his/her own SIM card given by the organization (Leung, 1390). Mobile phones are used to communicate, these systems and similar digital platforms take an important role in refugees' daily life. It is a vital way to keep them "online" with their friends and whom they concern. In the study of "Smart Cities Solution..." (POL CATALÀ, 2018) researchers proposed some innovative solutions to improve the service of connectivity in refugees‟ camps as long as the camp area as the facilities and fundamental factors. The following recommendations are as defined:

1. Bring the WIFI to longer distances assumed to be the most affordable solution for camps. Extended WIFI could be a suitable solution to motivate refuges to access Internet.
2. The technology aspect of 5G is possible solution for bringing mobile and adjusted operator at a wide band of frequencies. Nevertheless, the cost of this solution could be high and complicated as well in distance areas.
3. Internet of Things (IoT) is convenient in rural areas. Its cost is less than other options of connectivity. This technique let the devices that receive signals gather data and communicate it over wide areas. LPWAN and Internet of things are promising cheap for low data rate applications and block chain and machine learning facilitate the data storage and analysis respectively (POL CATALÀ, 2018).
4. Nongovernmental organization started to make studies on digital education for refugees to be prepared to adapt ICTs. However, low skilled and literate refugees have been taken into consideration to find good method of using ICT among refugees' groups.

Humanitarian organization defined thro Internet access as a basic need for human and it strengthen the right of "freedom of expression in opinion" (Chavez et al 2016). Nongovernmental organizations support the ICTs usage among refugees as it raises the well- being of refugees. However, there is a lack of services provided in refugees‟ camps as we mentioned (POL CATALÀ, 2018).

2.3. Challenges of ICTs in Refugees' Camps

In Emergency situation, Red Cross provided some services to refugees to communicate, but the access of technology was limited or damaged. Great diversity of factors prevented the training of technology among refugees and asylum seekers. It could be authorities' sanctions on telecommunication systems, poor telecommunication coverage along with damaged satellite cables. According to the statistics of UNHCR, only 39% of refugees have the access to Internet networks through their mobile phones. With this limited amount, implementing ICT solution in phoned based would be difficult. Plenty of camps are placed in distance areas where connectivity is low or somehow unavailable. A paper called "Smart Cities Solutions for Refugees Camps" has presented a world map (Figure 1) showing the Internet available where large number of camps is located (POL CATALÀ, 2018).

Implementing ICTs in refugees' camps has another advantage that is implementing is Geographic Information System (GIS). This digital system is once used in Zaatari refugees back in Jorden to teach Syrian refugees how to capture the whole map of the camp. The UNHCR applied a project called Refugees for that purpose. It acknowledges the representative of the camp of the basic features of the camp, like the wires and pipes (POL CATALÀ, 2018).

Similar technologies are useful for the camp improvement solutions and literate refugees of the digital technologies to facilitate their lives. Furthermore, an alternative project of implementing GIS in refugees' camps was done for southeastern camps of Turkey. The study was divided into many geographic, community infrastructure and relevant danger standards. The study combined 10 cities of Turkey based on the southerners. The standards were collected and saved into GIS program to determine the availability of the camps for newcomers. After that, evaluation is done to expedite strategies for refugees' camps compering with the old traditional analysis methods (Çetinkaya et al., 2016).

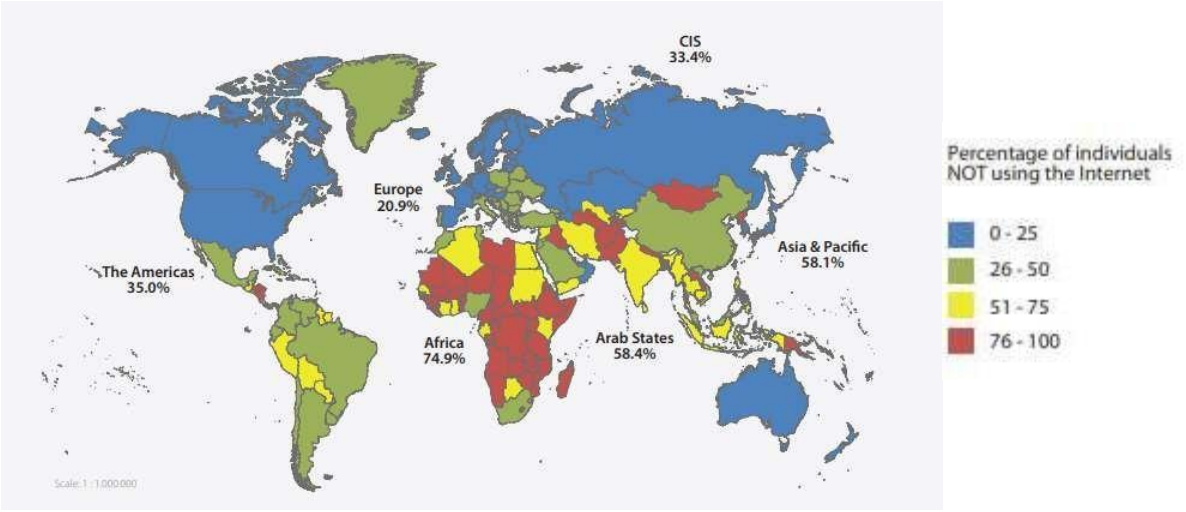

Figure 1 *Representation carried by ITU of the population percentage without internet access in 2015 (ITU, 2016)*

Through this paper we overviewed research done on applying ICT technology in refugees' camps based in Turkey. Not great number of studies has been done in that frame. As one of basis activities that makes refugees emotionally and incorporeally connected with their relatives, providing the digital techniques to use ICTs enhance refugees' well-being.

3. Conclusion

The act of putting ICTs technologies in the hand of refugees where they are trained with the essential abilities, performs a society of informative individuals to access information and connect dearly ones from far distance (Kabbar B., 2007b).

At all levels, camps are defined as a contemporary place for refugees to stay, but it might take years to whole life until the refugees are resettled to another region. Not only the survival needs should be taken in consideration, but also other important elements like communication technology and telecommunication should be considered as it is a main need for most of refugees (Schejter and Tirosh, 2017).

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Typological Classification of City Squares of Border Cities in the Eastern Region of the Republic of North Macedonia

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Abstract:

Abstract. The subject of this paper are the border cities in the eastern region of the Republic of North Macedonia - Makedonska Kamenica, Delchevo, Pehchevo and Berovo. For a long time, these cities were on the margins of the developments in the country and under a kind of domination by the larger centers in the eastern part of Macedonia.
The aim of this research is to compile and define a typological classification of city squares which will be a theoretical basis for a more detailed study of the principles and procedures through which city squares were formed, as well as their function in urban design and the life of city citizens.
This paper covers the contemporary various authors´ views on the phenomenon of urban typology, as well as the character of city squares as significant public spaces of cities, by observing the typology of squares, in order to study urban phenomena. The typological aspects of the squares are perceived through three thematic units: the position of the city square, the shape of the city square and the function of the city square.
Through the typology, urban and architectural features of the squares are perceived and their characteristics are determined, as well as the influences and relations of the urban micro elements on the public character of the squares (way of use of the public space by the inhabitants, presence of greenery, movement, approaches, visors, façade scenography, etc.).

Keywords: *Border cities; City squares; Urban typology*

1. Theoretical-Conceptual Framework of the Research

The subject of this research is an analysis of the typology of public urban spaces through which the spatial characteristics of the main squares are determined, their function and the manner of use by the inhabitants. The typology will analyze the architectural and urban elements in the city in order to identify, single out and group all the examples that have common features and to place them in a certain type.

In this paper, in addition to the classification of city squares, the characteristics of the squares will be explored individually as well as the influences and relations of the urban micro elements on them (greenery, movement, approaches, views, etc.).

The aim of the research is to compile and define a typological classification of city squares which will be a theoretical basis for a more detailed study of the principles and procedures through which city squares were formed, as well as their function in urban design and city life of citizens.

The research methodology for the needs of this paper consists of studying the primary sources - general and detailed urban plans of the cities as well as strategic plans adopted by the municipalities. Particular attention was paid to the study of cadastral data that provided insight into the demarcation of public and private land in cities, which was the basis for a graphic delineation of the annexes shown in this research. Also, secondary sources were studied and used - scientific papers of relevant architects and urban planners whose research helped in making the new typological analyzes of the cities in RNM that are the subject of this research. During the research period, visits were made to the cities where the goals, tasks were determined on the spot and specific field analyzes were performed for these cities. The end of this research resulted in a comparative analysis of the data resulting from the individual typological analyzes of each city square.

The expected results of this research are the initial basis that the local government should use in their definitions of strategic and action plans for development at the local level, in terms of development, transformation and improvement of public spaces in cities.

2. Historical and Demographic Development of the Cities in N. Macedonia

Following the genesis of the formation of settlements on the territory of today's RNM, it can be concluded that their occurrence dates back to ancient times. The purpose of their formation was with a strategic function - shelters and strongholds, they were economic, cultural and administrative centers of provinces and church centers. Defining a part of today's cities, ie. obtaining an autonomous urban physiognomy was done during the Ottoman rule (Nikoloska, 2003). With the development of handicrafts and trade, especially trade with highly developed European cities, the influences and way of life contributed to the penetration and gradually the small settlements to grow into urban areas.

The cities located in the eastern region of RNM, in the early twentieth century were small settlements that slowly began to develop into urban settlements. "Contrary to the long-standing tradition, Macedonian architecture in the first half of the 20th century divided the fate of a distant cultural periphery. This period did not create a new quality, but in the Macedonian periphery it helped to preserve the valuable urban units of the Macedonian cities. In that period, Skopje, the center of the Vardar banovina was built quickly, and the other cities, culturally and economically, were left completely behind. In small towns, people still lived in houses from the 19th century. " (Chipan, 1974). After the Second World War, in all Macedonian cities, for a short period of time, many factory complexes were built and operated with production halls in which the local population was employed. In this region, plants from the textile industry and the wood processing industry were opened, where a large number of workers worked.

During the 60s and 70s of the last century, within the SFRY, with the development of industry, the development of the city was emphasized to the detriment of the village and the rural economies. These differences still exist today, although a tendency for balanced development of cities and villages has begun (Table 1). Urbanization in that period made big differences between big and small cities and their

inequality. This is especially noticeable in the transition period, when these inequalities are expressed to the detriment of small towns because industrial technology has become obsolete and there has been a mass exodus from cities to the capital and even outside the country. This is especially noticeable in the young working age population so it can be noticed that in these cities, according to the age of the inhabitants, the population over 50 years prevails.

Table 1 Spatial and demographic parameters of municipalities and cities

Demographic parameters / City / municipality	Area of the municipality	Number of inhabitants in the municipality	Number of inhabitants in the administrative center	Number of settlements in the municipality
Makedonska Kamenica	190,37 km2	7.524	5.147	9
Delcevo	423 km2	16.170	11.500	22
Pehcevo	208,2 km2	4.881	3.237	7
Berovo	598,07 km2	12.813	7.002	9

3. Typological Discourse of the Research

The term "typology" is a coinage of two Greek words "tipos" - type and "logy" - science, according to which, in science, this term means a discipline that deals with the grouping and classification of types according to certain characteristics. Typology, as a type of research is an integral part of many scientific disciplines, such as linguistics, archeology, anthropology and others, which explains phenomena and processes and through various methods serves to classify, identify and analyze certain elements.

The basic term defined in the typology is the term "Type" from which various expressions such as "archetype", "prototype", "genotype", "phenotype", "model", "species", "class", "genus" and dr. The term "type" is defined as a template, mold, sample from which the term "typification" derives, which means "determining the unique properties of a product, stacking, grouping something according to the basic characteristics".

Architectural typology is also studied by important architects, including Christian Norberg-Schulz, Konstantinos Doxiadis, Rob Krier, and Vladan Djokic. Norberg-Schulz dealt with the typology of urban spaces, and according to him, it should be based on functional and formal aspects, or their combinations, and the urban whole can and should be observed through three interdependent elements in architecture - morphology, typology and topology (Norberg-Schulz, 1990).

One of the architects of "post-earthquake Skopje" Konstantinos Doxiadis, used typological network diagrams (so-called Existential networks) through which he explained the relationship between 5 elements - nature, man, society, networks and envelopes and put them in relation with anthropology, ecology, sociology, transport and architecture. This type of typological analysis is a useful tool for urban planning, urban planners and architects. The basic purpose and significance of the equity network is a simple and efficient method by which the complex factors used in urban analysis are placed in a certain relational system.

Rob Krier performed typological classifications of public spaces in terms of their shape and two-dimensional geometric shape. According to him, "the square is probably the first human invention of the urban space that occurs by grouping houses around a free space. This type of space (yard), was often the bearer of symbolic content, so it was chosen as a type for building many cult public places such as agors, forums, monastery yards, courtyards of mosques. (Krier, 2007)

For the urbanist Cliff Moughtin, one of the most important elements of urban design is the square. This is probably the most important way to design a good setting for public and commercial buildings in cities. A square is both an area surrounded by buildings and an area designed to expose its buildings to the greatest advantage. "The activity of the square is important for its vitality and, therefore, for its visual appeal." According to him, there are two main methods for categorizing public space - by function and by form. (Moughtin, 2003).

According to Djokic, the town square, as one of the basic urban elements, is a characteristic example of complex urban forms, which with the help of typology can be understood in the best way - its origin, development and transformation over time. According to him, the typological classifications of city squares can be crossed into two categories:

- typologies based on the diversity of square functions
- typologies based on the differences in the physical structure of the square. (Djokic, 2009)

3.1. Location on the Town Square

Because the city square is located in the spatial context of the built environment, its position is very important because it affects the morphology of the city. The relationship between its position in the city and the overall morphology of the city is of a mutual character and is variable over time. It is also an important, integral part of the built urban space. The following classification is made for the position of the city squares (Table 2).

Table 2 Categories and subcategories of the position of city squares

Categories and subcategories			
Location of city squares	**As part of the complete structure of the city**	**Individual squares**	**In the middle of the city**
			On the edge of city
			Between the middle and the edge
		Square systems	**Axial (linear)**
			Network (surface)
			Central (dotted)
	As part of the immediate environment	**At intersections**	**/**
		To significant buildings	**Square with a church**
			Square with a palace
			Square with a theater
		To the water surface	**/**
		On a high plateau	**Views towards the city**
			Views towards the nature

3.2. Town Square Shape

One of the most important architects who dealt with the urban typology of public spaces and squares of the XX century is Robert Krier who formed the classification based on the geometric shapes of squares. It lists 3 basic categories (shapes) - square, circle and triangle, on which its classification is based. Squares, according to their geometric shape are classified in Table 3.

Table 3 Division of squares according to their geometric shape

Square shape	**Squares that are directly related to the basic geometric shape**	**Squares with pronounced straight edges**	**Square**
			Rectangle
			Trapezoid
			Triangle
		Curved squares	**Circular shape**
			Elliptical shape
		Squares with straight and circular edges	**Octagon**
	Squares that are indirectly related to the basic geometric shape	**Shape as part of a basic geometric shape**	**Круг Circle**
			Ellipse
			Octagon
		Shape as a combination of several basic geometric shapes	**A large number of different possibilities**

3.3. Function of the Town Square

"The function of the town square is its basic characteristic because it is the initiation of its constitution and duration" (Djokic, 2004). Every social activity takes place in public spaces, and mostly in city squares. During the historical development of the squares, each of them had different functions, and most often more functions take place on the same square - public gatherings, political, religious, court gatherings, education, celebrations, trade and exchange, recreation and more.

City life can best be seen and felt in public spaces that allow communication, flow and intersection of various elements (people, vehicles, information, etc.). The character of the public space derives from its physical and functional features. The objects that directly appear on the squares can define their functions, as well as the spatial framework / form. ”Public spaces get their identity through the materialization and equipment they display for the standard and use of space. The applied materials, the surface treatment, the representation of the greenery and the design of the urban equipment reflect the specifics of the natural, social and technological context, the current needs and trends ”(Stupar, 2016).

There are many ways to divide or classify the function of city squares. However, a systematization is needed that will help in such a division of the squares, according to the factors that influence the social life in that environment, which can be constant or changeable. Thus, the functions of city squares, according to historical examples, can be placed in 2 categories:

1. Functions of the public space on the square - activities of open public space, which are not in relation to the surrounding buildings on the square. According to this, the squares can be divided into: market square, square - gate, military square, manifestation square, traffic square and park square.
2. Functions of the surrounding buildings around the square - activities that take place in and around the surrounding buildings on the square, which may affect it. According to this, the squares can be divided into: a square as a social / city center, a church square and a residential square.

3.4. Typological Classifications of Squares and Criteria for Forming Types

Each built environment has certain features and peculiarities by which it is recognizable. The circumstances in which the cities in RNM are created and developed have led to the formation of public spaces (city squares) with specific principles that are a result of the cultural, social and political context in which they were created.

Unlike Italy, Spain and other European countries in which there were rules regarding the continuity of elements and significant objects that formed the space of the city square, in our country is completely different. The buildings in the old European countries that formed a public space were representative, privileged buildings of the city, with great symbolism and significance, such as palaces, courts, churches and the like. which at a certain time had their own continuity of construction and existence. In Macedonia, there was no such continuity for the realization of such important buildings that could be a condition for the formation of a city square.

Mainly in the cities in RNM, from the 19th century, the city squares developed in three ways:

1. If the church that was the patron saint of the city, is located in the city center, then the square develops around the church
2. Squares develop either at the beginning / end of the bazaar, along their axis or in the middle of the bazaar
3. After the Second World War, when smaller cities were planned and developed urbanely, such as the cities in eastern Macedonia, the squares were planned in front of the administrative centers and in front of the big department stores, the so-called NAMA.

According to prof. Djokic, the most important procedure for forming a typological classification is to make a selection of relevant criteria on the basis of which the classification will be performed. Depending on the number of criteria and the number of possibilities of each criterion, the structure of the typology and the number of types are formed. The following 3 criteria have been selected with their principles through which it manifests itself:

1. Privilege - pretentiousness, recognizability, gaze, distinctiveness, control, orientation, symbolism
2. Protectiveness - security, privacy, shelter, seclusion, comfort, fencing
3. Constitutively - movement, spontaneity and approach.

The city squares in the cities of Eastern and Southeastern Macedonia have their own key garments that are related to its functional and morphological characteristics, therefore, their typological classification should be based on these three criteria. The criteria of privilege and protectiveness combine the morphological and functional characteristics of the squares and refer to the suitability between the function and the shape of the square. The criterion of constitutively refers to the position in the city and the character of the city structure, which is in fact its most important morphological feature.

Based on these 3 criteria, there are 3 types of classification, of which the criterion constitutively has 3 variants - linear, orthogonal and radial constitutively, and the criterion of privilege 2 variants - the existence of privileged buildings on the square and the absence of squares. The criterion of protection is not present in the squares of these 10 cities because none of them has protective elements. According to the performed analyzes of the squares, they can be classified into the following types (Table 4):

- **Type 1** - linear constitutionality with privileged objects
- **Type 2** - linear constitutionality without privileged objects
- **Type 3** - orthogonal constitutionality with privileged objects

However, if an analysis is made of the characteristic zones and elements of the city squares, and their position in the city in relation to the green zones, it will be noticed that the squares can be classified according to the following way:

- **Type A** - squares that are connected to the city park

- **Type B** - squares that are not connected to the city park

There is another way of classifying city squares, if one takes into account its position and location in relation to the geographical features of the city in which it is located. Since a common and important geographical feature of these 4 cities is the flow of a river that runs along the city and the formation of the city core and the settlements on both banks of the river, the squares can be classified as follows:

- **Type X** - squares that are formed next to the river bank
- **Type Y** - squares that are formed separately from the river bank

Table 4 Typological classification of squares

City/ Type	Makedonska Kamenica	Delcevo	Pehcevo	Berovo
Type 1		√		
Type 2			√	
Type 3	√			√
Type A		√		
Type B	√		√	√
TypeX	√	√	√	
Type Y				√

4. Typological Characteristics of Squares

4.1. Makedonska Kamenica

The town of Makedonska Kamenica is located in the eastern part of the RNM, under the slopes of the Osogovo Mountains and on both banks of the Kamenicka River. It is 90 km away from the capital Skopje. The city square in Makedonska Kamenica is located in the middle of the city, on the right bank of the river (Figure 1). It was built in 2011 next to the city church "Uspenie na Presveta Bogorodica" (Успение на Пресвета Богородица).

The shape of the square is not determined by the surrounding buildings, but by the area that was free before its construction.The accesses to the square are pedestrian and are located on all 4 sides through pedestrian streets and paths.

Generally, the square is divided into two parts - the main area of the square and the raised plateau on which the church is located, which is a privileged building, as well as the symbol of the square.Due to its correct geometric shape, the square is symmetrical. The main buildings and views of the square are the two buildings. From the south side of the square, the first building that can be noticed is the church, which dominates in the open space due to its size and central placement on the raised plateau, while from the west side the administrative building can be seen.

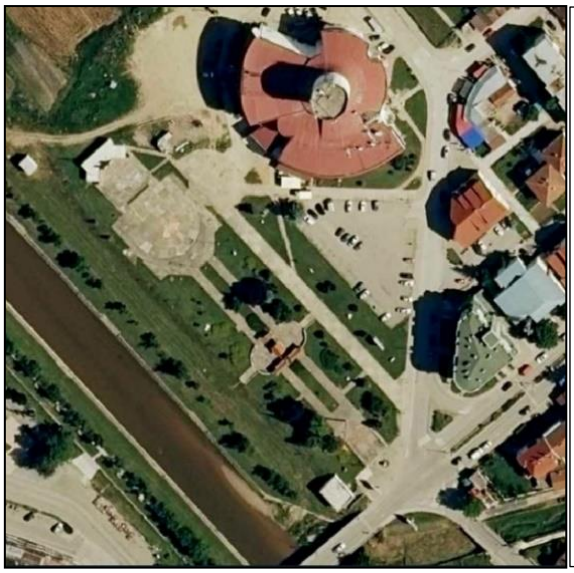
The square in Makedonska Kamenica has an orthogonal constitution with a privileged building - a church. The square is not connected to the city park, and is located next to the river where it is connected to a quay promenade.

Location in the city: central
Area: 2,540 m2
Shape: square
Privileged buildings: 1, church
Protective elements: /
Objects around the square: 3
Monuments: /
Greenery: grass and flower areas
Water surfaces: 2, fountains
Traffic: side street with parking
Plateau: 1, in front of the church
Function: religious, manifestation

Figure 1 Satellite view of the square, R 1: 1000

4.2. Delchevo

The city of Delchevo is located in the area of Pijanec and is one of the easternmost cities in the country. It is 111 km away from the capital Skopje, 27 km from the neighboring city of Pehchevo, and 11 km from the border crossing with Bulgaria "Crna Skala".
The city square in Delchevo is located in the central part of the city, on the east coast. It was built in 2018, with an area of 3000 m2.
The city square in Delchevo has a linear, geometric shape (Figure 2). The shape of the square is obtained by "connecting" two paths through two free surfaces, in the central part an ellipse, and in the extreme northern part a square. The shape is also determined by the planned activity and the area along the river, and not by the surrounding buildings.
Due to the complex shape, the square has 5 free areas, a plateau for holding events - in front of the stage, in front of the cultural center, the main plateau, the central elliptical plateau and the plateau at the beginning of the square
The square in Delchevo has a pronounced linear constitution with a privileged building - a house of culture. The square is connected to the city park, along the river, without a direct connection to it.

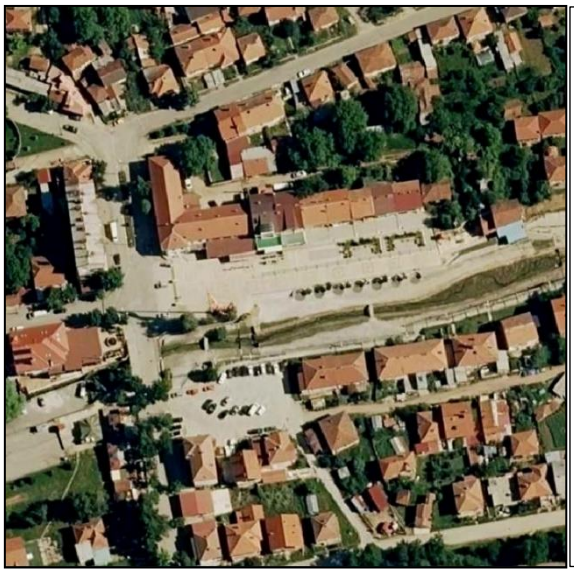


Location in the city: central
Area: 3,000 m2
Shape: linear, geometric
Privileged objects: 1
Protective elements: /
Monuments: /
Greenery: park
Water surfaces: /
Traffic: side street with parking
Plateau: 1, in front of the cultural center
Function: park, manifestation

Figure 2 Satellite view of the square, R 1: 1000

4.3. Pehchevo

The city of Pehchevo is located in the extreme eastern part of RNM, in the area of Maleshevo and is the easternmost city in the country. It is located at 1,158 meters above sea level. It is 124 km away from the capital Skopje and 10 km from the neighboring city of Berovo.
The city square in Pehchevo is located in the center of the city, on the east coast. Built in 2014, on an area of 2,500 m2, named St. Peter and Paul (Св. Петар и Павле).
The square in Pehchevo has a linear, rectangular shape (Figure 3). The new look of the square was made in 2014 on the site of a small green area. Across the north side of the square, along its length, there are linearly placed buildings, of catering character. Their front facades directly form the northern contour, while the curved flow of the river on the south side forms the southern contour and the border of the square.
The square has 2 levels, the lower level is by the river where there are 7 semicircular seating areas and the upper level which is the largest by area. There are 4 free areas on the square that are on both levels.
The square in Pechevo has a linear constitution without privileged buildings. The square is not connected to the city park and has no major city greenery, and is located next to the river and is connected by a free area - a plateau that is located on the level of the square and passes into the riverbed.



Location in the city: central
Area: 2,500 m2
Shape: linear, rectangular
Privileged objects: /
Objects around the square: 7
Protective elements: /
Monuments: /
Greenery: flower arrangements
Water surfaces: /
Traffic: side street with parking
Plateau: 2
Function: social, manifest

Figure 3 Satellite view of the square, R 1: 1000

4.4. Berovo

The city of Berovo is located at an altitude of 986 meters below the slopes of the Maleshevo Mountains. It is 161 km away from the capital Skopje, and in its vicinity is the new border crossing Klepalo, which was built by RNM, the access road and the border crossing, and is under construction on the Bulgarian side.
The city square in Berovo is located in the old city core and was built in 2010 with an area of 2,700 m2 (Figure 4). The name of the square is Dimitar Berovski (Димитар Беровски).
The square has a regular rectangular shape, defined by 3 buildings on the north, east and south side, while a street passes on the west side. The main feature of the square is the church "Rozdestvo na Presveta Bogorodica" (Рождество на Пресвета Богородица), which is located on the north side. The main views of the square are the buildings that surround it. However, the most important view is the church and the bell tower which stands out with its height. It is a representative and privileged element of the square.
The free areas of the square are located on its sides and in the middle. The square is on one level and there is no leveling or appearance of a plateau.

The square in Berovo has a pronounced orthogonal constitution with a privileged building - a church. The square is not connected to the city park nor does it have city greenery and is not connected to the river.

Location in the city: sideways
Area: 2,700 m2
Shape: rectangular
Privileged buildings: 1, church
Objects around the square: 3
Protective elements: /
Monuments: 1
Greenery: /
Water surfaces: 1, fountain
Traffic: traffic and pedestrian street
Plateau: /
Function: social, manifest

Figure 4 Satellite view of the square, R 1: 1000

5. Comparative Analysis of the Squares

The comparative analysis of the city squares, in terms of urban typology will be done in 4 categories: position of the square, area of a square, square shape and square function.

The position of the city square in the cities in RNM can be analyzed within the overall structure of the city and within the immediate environment. In terms of the overall structure of the city, the city squares of the cities of Makedonska Kamenica, Delchevo and Pehchevo, have a central position, while the town square of Berovo has a lateral position in relation to the overall shape of the city, but central in relation to the old city core.

In relation to the immediate surroundings, the city squares were formed either within / near the city park or along a water surface - a river. The square of the city of Delchevo is located near or within the city park, while the squares of the cities of Makedonska Kamenica, Delchevo and Pehchevo are by the river. However, there is such a square that is not connected and is not close to either the river or the city park, such as the town square of Berovo.

The function of the city square is a basic element of its appearance where it has developed together with the city throughout history - in case it is a square formed with the formation of the city or a new square designed with the expansion of the city. The significance of the function of the square is important because it defines its position and size.

Characteristic of these small border towns is that in addition to the basic classifications of city squares, a new function is obtained, and that is the social one. According to the tradition in these cities, the bazaar function was dominant because the population in that area performed all social needs, primarily trade, crafts and catering. With the demise of the function of the bazaar, that function was taken over by the squares with the primary role of socializing people.

A detailed comparison of the shape and function of the squares is shown in Table 5.

Table 5 Comparisons of the shape and function of squares

Characteristic elements of a square / City	Area of a square	Square shape	Square function	Location on the town square
Makedonska Kamenica	2.540 м2	Square	Social, Manifestation, Religious	Central
Delcevo	3.000 м2	Linear, geometric	Social, Park, Manifestation	Central
Pehcevo	2.500 м2	Linear, rectangular	Social, Manifestation	Central
Berovo	2.700 м2	Rectangular	Social, Manifestation	Sideways

6. Conclusion

City squares are the largest free public spaces that are formed either in front of religious buildings - city churches or within the bazaars.

Interventions in recent years are noticeable in terms of ground floor arrangement of squares, where the largest interventions are made in paving and urban equipment. The analysis of these squares will be the basis for the preparation of architectural-urban projects where it is of particular importance to follow the development of the squares and the other development of the cities and to be an urban fabric of connecting the city.

The future development of city squares can be considered in two ways, as a process of transformation of existing squares and a process of forming new squares. The same principles should be applied to both processes depending on the existing situation in which the square is located. Analyzing the cities that are the subject of this research, according to their size and function, there is no possibility for the formation of new squares elsewhere, but only the reconstruction of the existing city squares. In order to successfully realize the future reconstruction and transformation of the squares, their features should be presented that contribute to the improvement of their characters and qualities. The quality of the square is obtained according to the possession of certain specifics and characteristics.

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Quality Considerations and Standard Norms in the Production and Application of Wood Composite Decks

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Abstract:

Wood plastic composite (WPC) is defined an engineered wood composite made from wood and other lignocellulosic waste and thermoplastics. The WPC is durable composite for outdoor applications due to its good properties such as water resistance, high biological durability, good dimensional stability, and long life with low maintenance. Due to increasing price of African outdoor wood decks, the WPC decks have replaced with expensive massive wood decks. The raw material characteristics and production parameters significantly affects the quality properties of the WPC decks. Even the WPC is perfectly produced in the factory, assembly flaws such as wrong span length may results is failure in WPC decks. Furthermore, wrong use of WPC decks in service may cause cracks in WPC decks. In this study, the quality considerations in terms of production parameters of WPCs and correct processing conditions are analyzed. The problems caused by wrong use are explained. In addition, the European standards specifying the requirements of the WPC decks are given in this study.

Keywords: *Wood plastic composite; Wood composite deck; Engineered wood products*

1. Introduction

Wood Plastic Composite (WPC), also called as biocomposites, can defined a composites containing wood fibres or particles and thermoplastics, process additives. Thermoplastics can be repeatedly melted and this allows the recycling of the WPC. The main two components are thermoplastic and wood in the production of the WPC. The additives are coupling agent lubricant, UV absorbant, antioxidant, color pigment, moisture absorber, fire retardants, biocides, and mineral filler (talc, calcium carbonate, dolomite). The manufacturing process additives are lubricants, antioxidants and property enhancers (Oksman and Sain 2007).

A. **B.**

Figure 1 *A: The granules from the wood and thermoplastic; B: The WPC products*

Wood is the most used reinforcing filler in the WPCs. In general, the wood filler content in the WPCs varies from 30 and 70 wt%. The predominant technology is the extrusion process which produce the endless profile in the WPC production. Another processes are, injection molding (three-dimensional forms) and hot press molding. The WPCs are mainly used for outdoor applications such as decking, siding, fencing, window and door frames, and indoor furniture (Ayrilmis et al., 2021).

Figure 2 *Examples of wood fibres and wood flour used in the WPC production*

The ideal wood requirements for the WPC production are given below:

1. Wood should not have any biological degradation by insects of fungi
2. Wood should have a moisture content lower than 1% based on the oven-dry weight of wood.
3. Wood should have minimum extractive content.
4. Wood materials with a density between 0.35-0.65 g/cm3 can be proceed better in the chipper or grinder.

5. In general, softwoods are preferred because the process speed in the extruder is higher than hardwoods due to their higher lignin content
6. The bark should be removed from the logs.
7. Wood should have the optimum particle size depending on the process such as extrusion or injection molding

2. The hydrophilic structure of natural fibers (hydroxyl groups)

The hydroxyl groups in natural fibres can react with water molecules, which cause the linear expansion/shrinkage, and water absorption, thickness swelling of the composites. The natural fibres should be dried below 1% based on the oven-dry weight of wood before processing in the extruder (Ayrilmis and Ashori 2015). Otherwise, high moisture content in natural fibres can cause micro voids, gaps, and micro bubbles in the polymer composite. These problems can decrease the mechanical properties of the biocomposites. This also causes the dimensional changes and water absorption of the composites, which results in warping in service life.

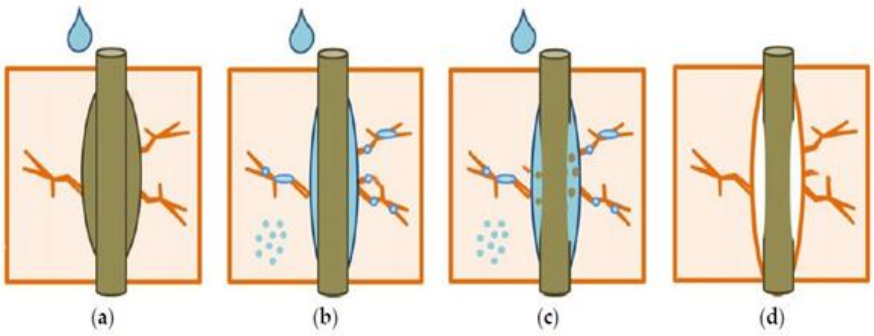

Figure 3 Physical degradation of interfacial bond between polymer and natural fibre caused by moisture and water absorption a) Development of micro-cracks and thus expansion of swollen fibre. b) Water molecules diffused in the matric flow along the fibre-polymer matrix interface. c) Water-soluble components leached from wood fibre. (d) Ultimate polymer matrix-wood fibre debondings take place (Azwa et al. 2013)

One of the most important problems of natural fibres they are “natural”. Therefore, the natural fibres can be degraded by fungi under suitable conditions such as enough oxygen, temperature, and moisture content. The biocidies such as zinc borate, borax, and boric acid are used to improve the biological durability of WPC are used.

Figure 4 The mildew spots on the WPC deck

The thermal stability of natural fibre some of the important factor for selecting for natural fibre composites because it influence the technological properties significantly. The thermal stability of natural fibres may differ from each other. The structural components of lignocellulosics, hemicellulose, cellulose, and lignin can be thermally degraded at high temperatures. Especially, the temperature in the extruder, injection molding machine or hot press molding should not be higher than 200°C, thus lmitis the thermoplastic types. Mostly, petroleum based thermoplastics such as polyethylene (PE), polypropylene (PE), polivinil chloride (PVC), polistiren, and biodegradable plastics such as polilactic acid (PLA) and Polybutylene adipate terephthalate (PBAT) are commonly compound ed with lignocellulosic filers because their melting temperature is lower than 200°C.

The slenderness ratio (length/thickness of the particle or fibre) and filling rate are two important parameters affecting the physical and mechanical properties of theWPCs. Until a certain level of the slenderness ratio of the wood material improve the mechanical properties, especially the tensile and flexural modulus. Previous studies reported that the WPC produced with the wood fibres shows better mechanical properties as compared to the wood particles (Stark and Rowlands, 2003; Basiji et al., 2010). As for the filling rate, increasing content of the wood particles or fibres improves the mechanical properties of the WPC, but higher amount of the wood material cause to the agglomeration problem, microvoids and gaps in the WPC. Thus results in non-uniform dipsersion of wood particles or gibers in the polymer matrix. Effect of fibre content on the physical and mechanical properties of the WPC is presented in Figure 5.

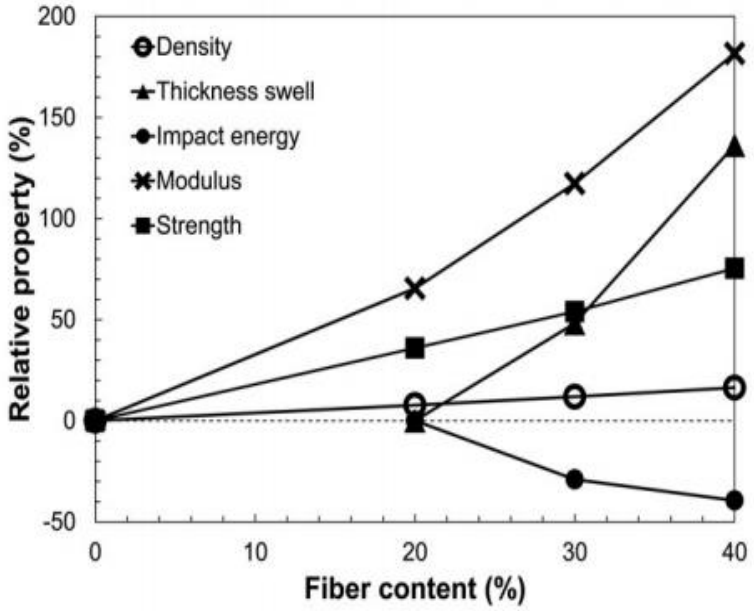

Figure 5 *Effect of fibre content on the relative physical and mechanical properties of the WPC (Migneault et al. 2014)*

As shown Figure 4, the modulus and strength of the biocomposites enhanced with increasing content of the filler. Particularly, the modulus significantly improved with increasing content of the filler content upto 40 wt%. However, the impact strength was negatively affected by the increased filler content due to the rigid structure of the filler. Polymer matrix absorb the energy and the impact strength of neat thermoplastic is bettern than wood material. In general, according to the literature, the modulus of the thermoplastics increase up to 60-70% of thr filler content while the strength values increase to 40-50 wt% of filler content as the compatibilizer is used.

Main factors influencing the technological properties of biocomposites:

- Plant fibre type and its properties including harvest time, extraction method, slenderness ratio, fibre-treatment and fibre loading rate
- Natural fibre length, orientation and weight percentage loading
- Choice of polymer matrix
- The addition of the Compatibilizer to improve the compatibility between polymer and plant (improvement in the interfacial bond)
- Dispersion of the plant fibre in the thermoplastic
- The orientation of the plant fibre in the thermoplastic
- Process parameters in the manufacture
- Presence of porosity and microvoids

Supervision of physical and mechanical properties of WPCs:

- Bending properties
- Immersion in boiling water (boil test)
- Slip resistance
- Bending performance under long-term loading
- Performance under cyclic climatic stress
- Performance under falling ball test
- Linear thermal expansion coefficient
- Weathering resistance
- Immersion in cold water
- Dimensional accuracy

Some modification techniques for enhancing physical and mechanical properties of WPCs:

- **Modification of wood surface:** Surface modification makes wood surface compatible with the polymer and improve the interfacial bond. These modifications includes corona, plasma, alkaline treatment, acetylation, thermal-treatment. Recently, environmentally friendly technique that is biological modification has been developed. In general, most of this techniques remove the percentage amount of the hydroxyl groups from the wood surface and makes hydrophobic surface and removes the hemicelluloses and lignin (Ayrilmis and Ashori, 2005).
- **Compatibilization:** Compatibilization, also called as coupling agent, is defined as the incorporation of a chemical substance into the formulation to enhance interfacial bond between wood and polymer. The most commonly used coupling agents are maleic anhydride grafted polyethylene (MAPE) and maleic anhydride grafted polypropylene (MAPP). The **Compatibilizers** chemically react (ester bonds) with the free hydroxyl groups of the wood cell) and make chemical bridges between wood and polymer matrix. It improves technological properties of the WPCs (Ayrilmis, 2013).
- **Addition of nanoparticles:** Organic or inorganic nanoparticles improve the physical, mechanical, thermal, and fire properties of the WPCs. Recently, the utilization of the nanocellulose in the WPC production has increased. The incorporation of the nanoparticles influences the crystallization of polymer during which leads to enhance properties for the WPCs (Oksman and Sain, 2007).
- **Hybridization of wood fibres:** Hybrid WPCs includes the mixture of two or more different wood fibers or sizes as reinforcing filler in one biocomposites.
- **Blending of thermoplastics:** Polymer blends can be used to improve the physical and mechanical properties of the WPCs as well as to reduce the cost. Thermoplastic blends makes synergic effect and it enables to obtain new thermoplastic with characteristics better than the individual thermoplastics.

CEN (European Committee for Standardization) published the required physical, mechanical, fire, thermal, and biological properties of the WPCs for different usage areas as EN 15534 standard in

2014.This standard is entitled as “The characteristics and specifications of composites made from cellulose-based materials and thermoplastics (usually called wood-polymer composites (WPC) or natural fibre composites (NFC))”. The EN 15534 consists of 8 divisions which are given in as follows:

- Part 1: Test methods for characterisation of compounds and products
- Part 2: Load bearing applications - Determination of modification factors for bending properties
- Part 3: Specifications of materials
- Part 4: Specifications for decking profiles and tiles
- Part 5: Specifications for cladding profiles and tiles
- Part 6: Specifications for fencing profiles
- Part 7: Specifications for general purpose profiles in external applications (outdoor)
- Part 8: Specifications for outdoor furniture

3. Conclusions

The market of WPC decks have rapidly increased in last two decades due to their excellent properties as compared to the solid wooden decks. Decking industry is the biggest market of WPCs. The consumers prefer WPC in outdoor applications due to its superior properties instead of solid wood.The decks are mostly produced by profile extruder and the wood material characteristics significantly affects the properties of WPC deck. The quality properties of the WPC decks are considerably influenced by raw material characteristics and process parameters. Tree species significantly affect the quality of the WPC. The raw material characteristics of wood such as moisture content, particle size and it is filling content in the polymer matrix, extractives content, fungal deteriotion of wood should be carefully checked. The EN 15534-4 standard specifies the minimum requirements of the WPCs for outdoor application. The WPC deck producers tests their products according to to the EN 15534-1 and the results should meet the requirements in EN 15534-4 standard. Especially, the average value of maximum failure load in bending should be above 3300 N and deflection should be maximum 2 mm at 500 N. The WPC should resist to falling mass (1000 g) at least 700 mm. Linear thermal coefficient between -20 and +80 C should be maximum 50. 10-6 K. Furthermore, the maximum water absorption after 5 h boiling in water should be 7%. The WPC producers should comply with the European Standards for gaining the optimum WPC quality and check their resulting WPCs regularly under laboratory conditions.

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Recent Developments in Production and Use of Inorganic Bonded Wood Composites in Structural Applications

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Abstract:

This study focused on the recent developments in the production and use of inorganic-bonded lignocellulosic composites, also knowns as cement-bonded wood composites, produced from lignocellulosics such as wood and non-wood particles, wood wool or fibers, and inorganic binders such as gypsum (plaster of paris), magnesia cement, portland cement. As compared to the traditional wood-based panels such as plywood, oriented strandboard, the inorganic-bonded composites have excellent properties such as flame resistance and biological durability, high water resistance and dimensional stability, and low-cost. Moreover, a widespread of lignocellulosics such as wood, non-wood, agricultural wastes can be used in the cement-bonded composites. They are used for acoustic reasons, thermal insulation, constructive frameworks, bearing purpose, acoustic application, siding application, fire and fungal protection, and other compliments in building and construction industry. Raw materials and additives significantly affects the properties of these composites, as well as production methods. The recent improvements in the production of inorganic-bonded composites and the applications were reviewed.

Keywords: *Inorganic bonded wood composites; Structural application; Engineered wood products; Wood-cement composites*

1. Introduction

Inorganic-bonded wood composites, also called cement bonded particleboard, is produced from wood or other lignocellulosic materials adhesive with hydraulic cement containing additives of chips under pressure. With the lightness, elasticity, workability properties of wood and; water resistance, biological durability, aging and impact resistant, High dimensional stability, durable to weathering and frozen conditions, and fire resistance of cement make the inorganic-bonded composite panel the excellent for the building applications (Simatupang and Geimer, 1990). First Inorganic-bonded wood composite factory was established in Austria in 1914.Cement bonded particleboard was commercially produced in 1974 by Dietekund in Switzerland. Cement bonded wood composites emits no toxic wastes during manufacture and employ an inert binder free from health risks associated with the use of resin bonded composites (Gündüz et al., 2018). Apart from the wood-based panels such as particleboard and fibreboard, the inorganic-bonded wood compositesdo not emit hazardous formaldehyde to the surroundings.

Inorganic-bonded wood composites are usually produced with a mixture of wood particles, inorganic binder, process additives, and water. The widely used inorganic binder is the cement and the setting process gives heat release due the hydration of cement in the presence of water. Portland cement contains different contents of CaCO3, SiO2, Al2O3, and Fe2O3. In addition, process accelerators ((Al2(SO4)3) considerably decrease pressing duration (Simatupang and Geimer, 1990). Na2SiO2 is used to remove sugars and extrractives from the wood before the mixing with cement.

Wood cement composites are produced from strands, particles or fibres of wood or other liginocellulosics mixed together with Portland cement as a inorganic binder. They are mainly used in construction industry. Wood cement composites are usually produced from a mixture of wood particles (wool, fiber or shavings), inorganic binder, process additives, and water. The most common inorganic component is the cement and the setting process results in heat release due the hydration of cement in the presence of water. Inorganic binders are either gypsum (plaster of paris), magnesia cement, portland cement, phosphate cement or a mixture of at least two of these compounds. The composition of the raw materials used in cement bonded particleboard is shown in Figure 1. The manufacturing process of cement bonded particleboards presented in Figure 2.

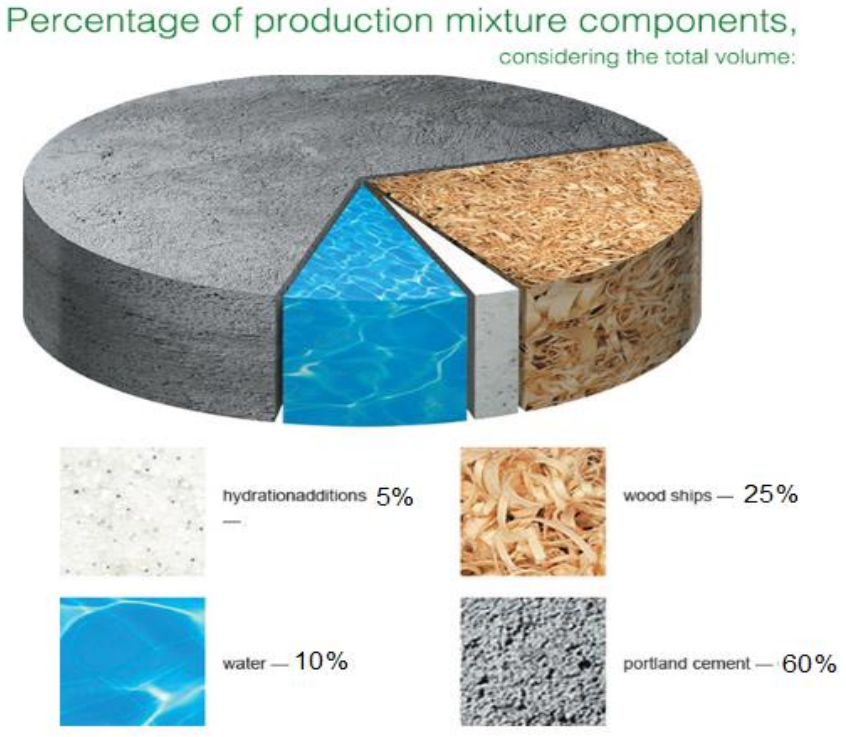

Figure 1 *The composition of the raw materials used in cement bonded particleboard*

Figure 2 Manufacturing process of cement bonded particleboard (Setter et al., 2020)

2. Inorganic-bonded wood composites

Advantages of inorganic-bonded wood composites in comparison with resin-bonded traditonal particleboards (Moslemi, 1995; Simatupang and Geimer, 1990; Setter et al, 2020):

- Aging and impact resistant
- High dimensional stability
- Resistant to extreme climate conditions
- Fire resistant (class A2)
- Good sound and heat insulation
- Frost resistant
- Does not emit formaldehyde like traditional wood-based panels
- High biological durability
- Easy to install

Inorganic-bonded lignocellulosic composites are used for constructive frameworks, bearing purpose, fire protection and other compliments for walls and floors. They also have good thermal and acoustic properties and they are competitive with reinforced concrete because of their relatively low density. Some building applications of the inorganic-bonded wood composites are presented in Figure 3.
The utilization of the inorganic bonded wood composites have considerably increased in the construction industry because they have high thermal insulating and sound absorbing properties as a function of high porosity and low density (generally 400-600 kg/m3). Consequently, because of the mineralization of the fibres, the panels have biological durability and fire resistance. Thus, the composites are used in buildings as roof, ceiling, and exterior wall where a high durability and low maintenance are needed. Cement bonded wood fibre composites have enhanced ductility, higher flexural modulus, crack resistance as compared to unfilled cement concrete (Mohr et al., 2004). Magnesia cement-bonded excelsior panels were the first inorganic-bonded composite panel produced on a continuous production line. The binder sets within minutes at higher temperatures. The major compound of magnesia cement is magnesium oxide.

Figure 3 *Siding applications of inorganic-bonded wood composites in buildings*

Heraklith (acoustic) panel: It is a wood wool panel produced from cement with a special wood shaving (wool). Heraklith panel was made with mixture of wood shavings and magnesite binder under the Heraklith brand, registered in 1923. Wood-wool acoustic panel is made of wood fiber, cement, and inorganics under high pressure. It has a porous structure which absorb noise. It is not only having great acoustic and decoration effect, excellent noise absorption, thermal insulation, and outstanding fire resistance but also environmentally friendly. Especially, theaters and cinema salons prefer heraklith panels because it does not reflect the sound from the wall. The heraklith panels are widely used thin structural walls in the building industry. It can be efficiently painted to obtain decorative surfaces. It is widely used as noise and sound barriers in autobahns. Applications of Heraklith panel with stone wool as heat and sound insulation, and fireproof material on wall and ceiling applications of Heraklith panel are presented in Figures 4-6.

Figure 4 *Heraklith acoustic panel produced with wood shavings and magnesia binder with the process additives*

Figure 5 *Heraklith panel with stone wool and ceiling applications*

Figure 6 *Application of Heraklith panel with stone wool as heat and sound insulation, and fireproof material on the surface of bricket wall; B: Ceiling and painting application of Heraklith panel*

Use of phosphate cement as binder in the inorganic-bonded wood composites is being increased in recent years due to its advantages. Phosphate cement has a significant advantage which is a fast setting binder formulated from an aqueous reaction between acid phosphate and alkali oxide or hydroxide (Amiandamhen et al., 2016). The potential use of magnesium based phosphate cement as binder for various agricultural waste such as bagasse, hemp hurds, pine sawdust, paper mill sludge, and wastepaper was investigated by Amiandamhen et al. (2016). They reported that the density of hemp panels varied from 0.59-0.83 g/cm^3, bagasse panels varied from 0.54-0.78 g/cm^3, pine wood panels varied from 0.58-0.84 g/cm^3, paper sludge panels varied from 0.68-0.81 g/cm^3 and wastepaper panels varied from 0.67-0.81 g/cm^3. They concluded that the phosphate inorganic can be efficiently used as binder for wood, non-wood, and agricultural residues. The physical properties of the panels complied with the minimum requirements for cement-bonded particleboards (EN 634:2007) and LD-1 grade particleboard (ANSI 208.1:1999).

The phosphate is nature-friend inorganic binder for the wood, wood fibre or wood wool composite panels. This is because the phosphate is not affected by the sugars and hemicelluloses in natural fibres while the portland cement is affected by the sugars, starch, hemicelluloses, and phenolics in lignocellulosics. Phosphate bonded wood composite panels are feasible for siding applications in the building industry because their density is low and durable to exterior weathering conditions. It is suitable for the applications of false ceilings and partitions, prefabricated and under-decking structures. Furthermore, phosphate bonded wood composite panels may be engineered for high strength and stiffness, and moisture resistant applications. When the binder content is increased, these panels can be also used in flooring systems. The development of phosphate bonded wood composite panels lead to improve national economy and environmental benefits. More recently, chemically bonded phosphate ceramic (CBPC) as binder was developed for building applications (Ceramicrete® technology based on

magnesium oxide). When compared to the traditional inorganic binders such as portland cement and gypsum, the CBPCs have inorganic inorganics having a lower amount of carbon content that are nature friendly binders (Amiandamhen et al. 2019).

3. Some key considerations in choosing wood material

The compatibility (interfacial bond) between the cement and wood surfaces is influenced by the wood material characteristics, type of cement, formulation receipt, wood/cement ratio, storage condition, wood particle size and wood quality. The main problem is that wood extractives prevent the cement setting, which results in lower mechanical properties for the cement bonded wood composites. In general, hardwoods are less suitable than softwoods because of the presence of large amount sugars in hardwoods. The storage time also affects the neutralization of wood and has an impact on the properties of the cement bonded wood composites. Generally, the outdoor storage time of the wood varied from 4 to 20 weeks which reduces the sugar content in the wood and improves the compatibility of the wood with portland cement. Portland cement is more sensitive to wood extractives as compared to other inorganics such as gypsum or magnesia cement because its hydration time is the longest in most cases.

4. Conclusions

Inorganic-bonded lignocellulosic composites are unique properties for structural applications. The waterproof and fireproof properties, heat and sound insulation properties, and biological durability, and esthetic appearance after overlaying make it excellent composite for outdoor applications. The addition of wood particle, wood fiber or wood flour into the different inorganic binders such as portland, magnesia, phosphates, and gypsum improve the bending strength and modulus of the elasticity of the composite panel. The manufacturers should consider the raw material characteristics of the wood such as sugar, starch, hemicelluloses, and phenolics which forms a barrier between the inorganic binder and lignocellulose material surface. This negatively affect the physical and mechanical properties of the composite panels. Mostly softwoods are preferred for the inorganic-bonded composites such as pine, spruce. Agricultural wastes and recycled wood can be successfully used in the composites. As compared to the traditional wood-based composites such as particleboard and fiberboard, the production line of the lignocellulosic bonded particleboards is more simple and lower production cost. The market reports inform that the global production of inorganic-bonded wood composites will increase in the world as a function of developing construction industry. Recently in Europe, inorganic-bonded wood composite panels have been developed for sound barrier walls and fire rated partitions.

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Critical Seismic Shaking Table Tests Near Resonance of Large-Scale Bridge Model with DSRSB Isolation and V-MG Energy Dissipation Devices

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Abstract:

Extensive experimental and analytical research have been performed, led by the third author during three and a half years, in the Institute of Earthquake Engineering and Engineering Seismology (IZIIS), Ss. Cyril and Methodius University in Skopje, in the frame of the innovative NATO Science for Peace Project "Seismic Upgrading of Bridges in South-East Europe by Innovative Technologies (SFP: 983828)", involving five countries. The specific project part included development of the innovative USI-V-MG system representing advanced technology for seismic isolation and seismic protection of bridges. By integrating the new uniform vertical multi-gap (V-MG) energy dissipation devices, qualitative advances of the USI-V-MG system have been achieved. In this paper are presented and discussed original observations resulting from conducted complex, unique and critical near resonance shaking table tests of constructed large-scale bridge model. The extensive experimental research program is realized on a bridge model constructed by using the seismically isolated system upgraded with uniform vertical multi-gap energy dissipation devices (USI-V-MG). The installed adaptive system for seismic protection of bridges utilizes originally produced double spherical rolling seismic bearings (DSRSB) as seismic isolators, while qualitative improvement of seismic performances is achieved through the use of novel uniform vertical multi-gap energy dissipation (V-MG-ED) devices.

Keywords: *Shaking table; Bridge model; Seismic test; Passive control; Seismic isolation; Energy dissipation*

1. Introduction

In the past, extensive studies in the field of seismic isolation of bridges have been mostly performed in the world's renowned research centers in Japan, USA, Italy, and New Zealand. However, in the recent years, contributions from many other countries are increased and have resulted in proposing of many new ideas and concepts. The intolerable severe impacts to modern bridge systems during strong recent earthquakes [1, 2], have been observed. It has given rise to strong arguments about the further needs for development and practical implementation of seismic isolation systems in seismic protection of bridges, [3, 4, 5, 6, 7]. This paper shows the obtained important results from the realized creative research part of the innovative long-term study devoted to development of a new, experimentally verified, advanced USI-V-MG system that can provide qualitative seismic upgrading of isolated bridges by using of innovative V-MG-ED energy dissipation devices [8]. The conducted initial experimental part of the study included realization of original nonlinear quasi-static tests of the created individual energy dissipation components. Unique original experimental data have been obtained, enabling development of an advanced, experimentally validated, nonlinear micro-model for hysteretic behaviour study of the complete new vertical multi-gap energy dissipation (V-MG-ED) devices with possibility of optionally different arrangement of ED components. Following some recent author's developments [8], created were conditions for realization of the final original study involving shaking table tests of the constructed large-scale bridge prototype model with the applied new USI-V-MG system. The tested uniform upgrading system for seismic protection of bridges, USI-V-MG system, utilizes originally produced double spherical rolling seismic bearings (DSRSB) as seismic isolation system, while qualitative improvement of seismic performances is achieved through the use of novel uniform vertical multi-gap energy dissipation (V-MG-ED) devices.

2. Concept of New USI-V-MG Bridge System

The upgraded seismically isolated (USI) system with vertical multi gap (V-MG) energy dissipation (ED) devices represent newly created advanced technical concept providing harmonized modification and improvement of structural seismic response, Fig. 6. The USI-V-MG system is advanced alternative method for qualitative improvement of seismic protection of bridge structures through introduced concept of global optimization of seismic energy balance. The USI-V-MG system is created through obligatory incorporation of the following three complementary systems: ***(1) Incorporation of seismic isolation (SI) system:*** The applied system for seismic isolation of bridge superstructure should contain adequately selected seismic isolators that will provide very low stiffness in horizontal direction and will be capable of sustaining safely the total weight of the entire superstructure. In that way, it is enabled for an appropriately designed seismic isolation (SI) device to be installed at each supporting point of bridge superstructure whereas the total isolated weight will be directly transferred to the supporting middle piers and/or to the rigid supporting abutments of the bridge. Under such conditions, a wide range of possibilities of selecting the proper system for seismic isolation of bridge superstructure is given, including application of any newly developed advanced solutions for seismic isolation; ***(2) Incorporation of seismic energy dissipation (ED) system:*** Seismic isolators are characterized by insufficient damping for seismic energy dissipation, so additional seismic energy dissipaters have been introduced. For this reason, the ED devices should possess optimal stiffness, optimal bearing capacity and high ductility in relation to the seismic performances of implemented seismic isolators. Considered very large stiffness of the ED devices leads to undesired impact and impulsive transfer of inertial forces. To avoid such problem, it is favorable to reduce the initial stiffness of ED devices to an optimal level. In addition, if bearing capacity of ED devices is considered very high, large or critical forces will be transferred to the piers. To avoid related problem, bearing capacity of energy dissipation devices should be reduced to a design limit. Finally, the ductility capacity of ED devices should be sufficiently large. In the case of generated large inertial forces, relative displacements in full scale bridges can become quite large, of the order of 25-30 cm or larger. Therefore, the ED devices should possess the ability of

sustaining large deformations without damage. Generally, it is necessary to introduce ED devices with greater capacity of seismic energy dissipation through nonlinear deformations and creation of pronounced hysteresis curves. In the frameworks of this study, very significant advances of the three above specified properties are achieved by formulation of the proposed advanced V-MG multi-directional energy dissipation devices, and ***(3) Incorporation of displacement limiting (DL) system:*** In the course of very strong earthquake large relative displacements may occur and sometimes they are not successfully controlled in a reliable engineering mode. By introducing specific displacement limiting devices (DLD), strong impact and negative effects will be reduced or avoided.

3. Creation and Testing of Prototypes of V-MG Energy Dissipation Devices

Within the frames of the conducted study, special attention has been paid to the formulation of integrated compact unit providing highly ductile response, as well as, structurally to represent innovative multi-gap (MG) and multi-directional (MD) energy dissipation (ED) device of a unique and large seismic energy dissipation capacity. Here, briefly are described the main creation steps, original structure and testing of prototypes of new V-MG-MD-ED energy dissipation devices:

1) Structure of multi-directional V-MG-ED devices: The structure of multi-directional V-MG-ED device generally consists of: (1) base metal plate for fixation of the vertical cantilever components; (2) adequately distributed vertical energy dissipation components (EDC); and (3) upper metal plate with openings through which the energy dissipation components are activated based on gaps in different phases. Characteristic activation modes include very frequent weak earthquakes, reduced number of moderately strong earthquakes and rare, but possible, very strong and destructive earthquakes. The prototype model of the proposed V-MG-MD energy dissipation device, Figure 1, has been created considering several constituent parts that form a compact ED unit, including:

(a) Base plate: The base plate of the V-MG-MD energy dissipation device is manufactured in the form of a base circular metal plate (d = 25 mm) with a diameter of D = 450 mm. In the base metal plate, in each of the two concentric circles, eight regularly spaced equal openings with windings are made. The openings with windings are used to fix the vertical components by screwing. In the outer concentric circle with a diameter of d_1 = 340 mm, eight openings with windings are made for the fixation of the external eight vertical (V) energy dissipation components. In the internal concentric circle with a diameter of d_2 = 190 mm, spaced are other eight openings with windings for the fixation of the internal eight vertical (V) energy dissipation components. The diameter of the opening with winding is considered standard and provides the possibility of assembling different combinations of produced different types of vertical energy dissipation components, Table 1.

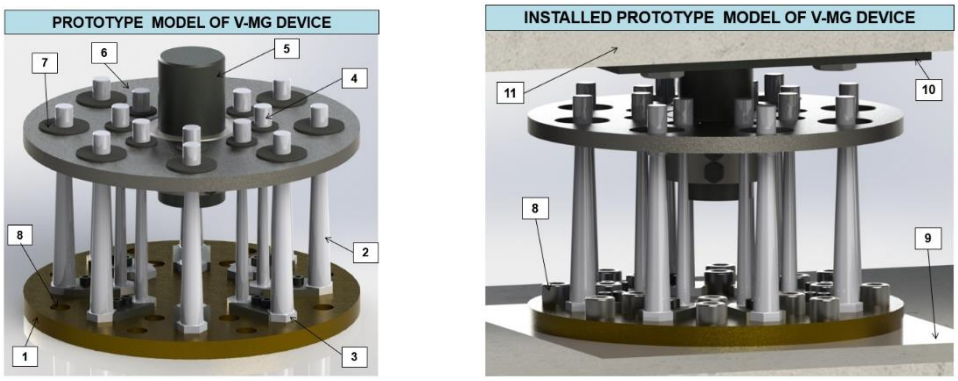


Figure 1 Prototype model of V-MG-ED device with installed V-MG-ED components: 1. Bottom fixing plate; 2. Outer V-MG components; 3. Bottom common fixing part; 4. Inner V-MG components; 5. Stiff central body; 6. Upper activating plate; 7. Gaps with distance protector; 8. Fixing bolts of base plate to substructure; 9. Substructure; 10. Upper plate fixed to superstructure; 11. Superstructure of prototype bridge

Table 1 Prototype models of V-MG-ED components

Prototype base-t	Prototype Notation	Geometry form	Geometry of gaps	Activation direction	Base-Db (mm)	Top-Dt (mm)
1	V-MG-MD-T11	T11	G1 & G2	MD	32.0	25.6
	V-MG-MD-T12	T12	G1 & G2	MD	32.0	19.2
2	V-MG-MD-T21	T21	G1 & G2	MD	28.0	22.4
	V-MG-MD-T22	T22	G1 & G2	MD	28.0	16.0
3	V-MG-MD-T31	T31	G1 & G2	MD	24.0	19.2
	V-MG-MD-T32	T32	G1 & G2	MD	24.0	14.4
4	V-MG-MD-T41	T41	G1 & G2	MD	20.0	16.0
	V-MG-MD-T42	T42	G1 & G2	MD	20.0	12.0

(b) Vertical ED components: The vertical energy dissipation components are made of a ductile metal in the form of a moderately steep cut cone. According to the diameter of the cone base (Db), there have been adopted a total of four options from which there have arisen four prototype types of energy dissipation devices, Table 1 and Fig. 2. For each type of energy dissipation device, there have been designed vertical elements with two alternative variants of cones, regarding the considered different diameters of the top (Dt), whereat the diameter of the element at the base has been kept the same. In that way, four base-type prototypes of energy dissipation devices have been formed, Table 1, each type with two variants of cones of vertical energy dissipation components as follows: (1) Base type-1 with options: a) prototype model T11 with base and top diameters Db/Dt=32.0/25.6 mm and b) prototype model T12 with base and top diameters Db/Dt=32.0/19.2 mm; (2) Base type-2 with options: a) prototype model T21 with base and top diameters Db/Dt=28.0/22.4 mm and b) prototype model T22 with base and top diameters Db/Dt=28.0/16.0 mm; (3) Base type-3 with options: a) prototype model T31 with base and top diameters Db/Dt=24.0/19.2 mm and b) prototype model T32 with base and top diameters Db/Dt=24.0/14.4 mm; 3) Base type-4 with options: a) prototype model T41 with base and top diameters Db/Dt=20.0/16.0 mm and b) prototype model T42 with base and top diameters Db/Dt=20.0/12.0 mm. All vertical components have the same height of the cone body of h1 = 190 mm and end with an identical cylinder with a diameter d = 24.0 mm with a constant height of h2 = 60.0 mm. With the adapted geometry of V-MG components, provided were equivalent conditions for fixation into the base plate, while the standard cylinder at the top provided equivalent gap-G1 and gap-G2 conditions for gap-based excitation (alternatively repeated contact and activation).

(c) Activating plate with holes: On the upper side of V-MG device, metal plate with thickness d=20.0 mm is constructed with openings with different diameters distributed along two concentric circles. The inner 8 openings are constructed with diameter d3=34.0 mm. Having standard top cylinders with diameter of d=24.0 mm, a gap of G1=5.0 mm was provided in all directions. However, the external 8 openings are constructed with diameter d4=60.0 mm. Having top cylinders with diameter of do=24.0 mm, a gap of G2=18.0 mm was obtained in all directions. The upper metal plate is fixed to the central stiff body for which is assured strong connection to the superstructure of the large-scale bridge model. With presented original structure of V-MG device, activation of the inner ED components will start after relative displacement becomes larger than 5 mm in all directions. If relative displacement exceeds 18.0 mm, then activation of all ED components located on the external concentric circle takes place

Figure 2 Cyclic testing of V-MG-ED devices (left) and Performance of EDC with simulated gap-G2 (right)

2) Testing of prototype models under cyclic loads: Within the frames of experimental testing of produced model prototypes of V-MG energy dissipation components, an ample experimental program has been realized. Each individual V-MG component has been tested twice. First test-1, representing original test, was conducted to define hysteretic response of V-MG component under the initial conditions. Second test-2, representing repeated test was performed to get an insight into the hysteretic response of the model that has already been tested.

For testing of 8 prototypes of the V-MG components under cyclic loads, simulating gap-G1 in the first case and gap-G2 in the second case, a total of 16 components of type-V have been produced. With the anticipated realization of the original and the repeated tests of each component, a total of 32 nonlinear cyclic tests have been done. Based on performed detailed analysis the recorded extensive volume of original test results, hysteretic gap-based response and high energy dissipation properties have been defined for all V-MG component prototype models, Fig. 2.

4. Refined Modelling of V-MG-ED Devices and Components

An important research part included refined modelling and hysteretic response simulation of innovative prototypes of V-MG-ED devices and components, Fig. 3. Nonlinear numerical analysis has been carried out using the formulated refined or micro-models of the created and tested model prototypes. Commonly, cyclic displacement of up to ±45mm in X direction has been simulated through the upper plate, with a step of 5mm increase in each cycle. The mathematical model represented refined 3D finite element mesh of installed cantilevers (vertical components), fixing base plate and upper plate used to simulate cyclic top displacements. Modelling and analysis of the hysteretic response and energy dissipation capacity of V-MG-ED devices and components has been done by the use of ABAQUS CAE software. With setting the real material characteristics, the element geometry, the contour conditions, the contact conditions, the imposed displacement conditions and other needed information, as well as, with providing refined discretization of the structure into fine finite element mesh, provided were corresponding conditions to compute results as exact as possible.

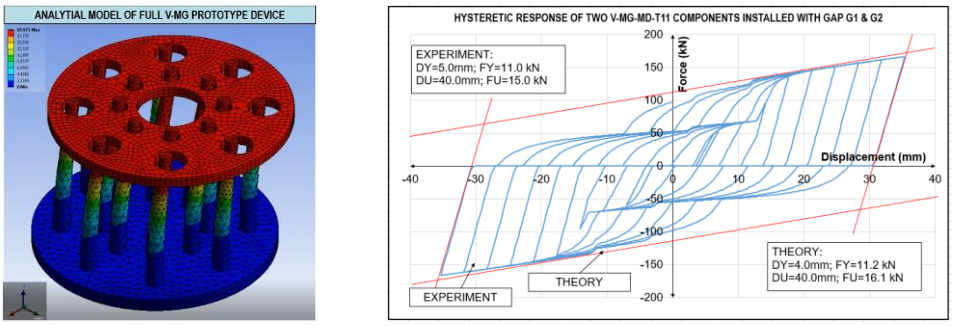


Figure 3 Formulated refined 3D ABAQUS model of full V-MG-MD-ED device (left) and computed hysteretic response of two V-MG-MD-T11 components installed with gaps G1 & G2 (right)

The calculations have been performed successfully, without shown any error during the step-by-step analysis process. Following the process of nonlinear micro-model formulation, considered and analyzed was the specific example of partial device, assembled with two identical V-MG-MD-T11 components with different gaps G1 & G2. The resulting original and characteristic gap-based hysteretic response of the system was successfully computed, Fig. 3, right.

5. Prototype Testing of DSRSB Seismic Isolation Devices

The seismic isolation (SI) system used within the USI-V-MG bridge model was assembled by the use of prototype models of double spherical rolling seismic bearing (DSRSB) devices having two large-radius spherical surfaces (Fig. 4), which were originally designed for the purposes of the planned various experimental investigation phases [5].

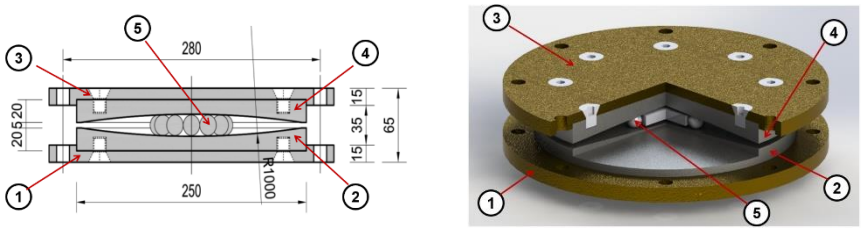
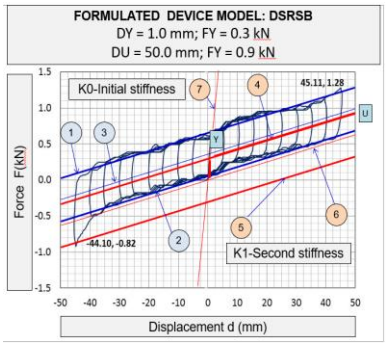


Figure 4 Prototype of designed, constructed and tested DSRSB devices: (1) Cross-section with geometrical properties and (2) Device view with characteristic cross-section (Commonly re-used prototype)

The design of such device was conditioned by several requirements: to provide the sufficient bearing capacity for vertical loads; to provide the sufficient displacement capacity; to have radii of curvatures of the spherical surfaces adequate to achieve the targeted period of vibration; to have a sliding surface generating minimal friction and to have a central rolling part providing minimum reactive friction force. The resulting device is shown in Fig. 4. The lower (2) and upper (4) spherical plates were constructed of a hard inox polished to a mirror shine, providing durability and very low friction. Its diameter was 250mm, while the radii of the spherical surfaces were 1000mm. Both plates were fixed to the lower (1) and upper (3) steel end plates with diameter of 310mm. The inserted central rolling part (5) was constructed in the form of a ring of twelve balls with a diameter of 18mm, distributed uniformly along the circle around cylindrical slider and spaced with their opposite centres at 74mm.



EXPERIMENTAL RECORDS:
(1) upper envelope curve (EC)
(2) lower EC
(3) symmetric line
(4) shifted upper EC
(5) shifted lower EC
(6) shifted symmetric line
(7) recorded initial stiffness

Quasi-static tests of isolation devices were carried out by the use of four DSRSB devices mounted at their original locations, two at each abutment. The RC slab, weighting 85kN, brought a vertical force of 21.25kN to each one. The representative hysteretic response for a single device is shown in Fig. 5.

Figure 5 Hysteretic response of tested DSRSB prototype [5]

From the response, it is clear that the device has a sufficient capacity for horizontal deformation, amounting to over 45mm and that the shape of the hysteretic loops forms a skewed rectangle, which leads to its representation with bilinear model, Fig. 5.

6. Seismic Shaking Table Tests of Large-Scale USI-V-MG Bridge Model

Due to the size of the seismic shaking table (5.0mx5.0m) and payload capacity, the originally designed USI-V-MG bridge prototype model had to be geometrically reduced in respect to the selected prototype. From those reasons, adopted was geometrical scale factor of 1:9, which verified the referred constraints in this case, but with adopted specific model design concept. As a consequence of the scale reduction, the relevant properties involved in the dynamic (seismic) tests were scaled according to a similitude law. Considering the main related factors, an adequate combined true replica-artificial mass simulation model was adopted. For simulation of the stiff RC superstructure, the stiff slab with added mass was adopted using the same material as that of the prototype structure. For simulation of the middle piers, steel material was used.

The seismic isolation and energy dissipation devices were designed and produced in reduced scale. The similitude law implies the adopted relations for the different parameters, all given in terms of the geometrical scale factor (lr). Concrete material type C25/30 has been used for construction of RC segments of bridge model, while for construction of steel V-MG devices, steel material type S355 was

selected and applied. Considering final proportions at the top level, the total length of the entire experimental bridge model is L = 740.0 cm + 2 * 20.0 cm + 2 * 25.0 cm = 830.0 cm. The RC deck is placed at a height distance of h_d = 40.0 cm from the highest RC substructure surfaces. This space (seismic gap) is used to install both, originally produced DSRSB devices, as well as the new V-MG-MD-ED devices, Fig. 6 and Fig. 7. After fabrication of all model segments and specific SI, ED and DL devices, as well as, after preparing the other testing connections and instrumentation devices, the large-scale USI-V-MG bridge prototype model was assembled and tested in the Dynamic testing laboratory of the Institute of Earthquake Engineering and Engineering Seismology (IZIIS) in Skopje. With adopted 20 active recording channels, approximately 5.000.000 numerical values were recorded in each single test. Realizing four original and four repeated tests, large experimental data volume, containing about 40 million numerical values, have been recorded, integrally processed and analysed. In Fig. 8, as example, presented are time history responses of displacements and accelerations recorded during seismic test under simulated real strong El-Centro earthquake scaled to PGA=0.78g. The conducted seismic shaking table tests have shown that upgrading of seismically isolated bridges with vertical multi gap energy dissipation devices represent a highly efficient and practical engineering option.

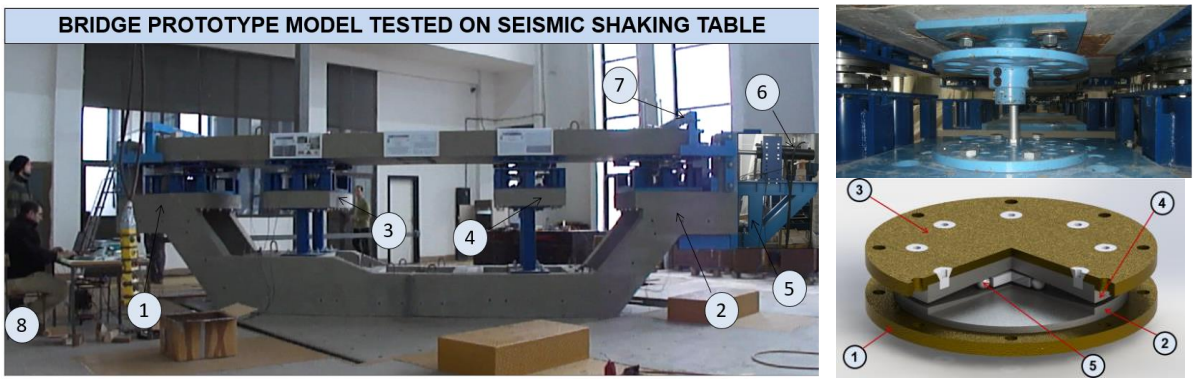


Figure 6 *USI-V-MG (BM-V) bridge prototype model on IZIIS seismic shaking table: Left end support (1); right end support (2); support above shorter piers (3); support above longer piers (4); actuator supporting structure (5); actuator (6); DL devices (7); computer controlling cyclic tests (8), (Left); and Right: Disposition of DSRSB devices (superstructure supports) and partially between set new V-MG-ED device.*

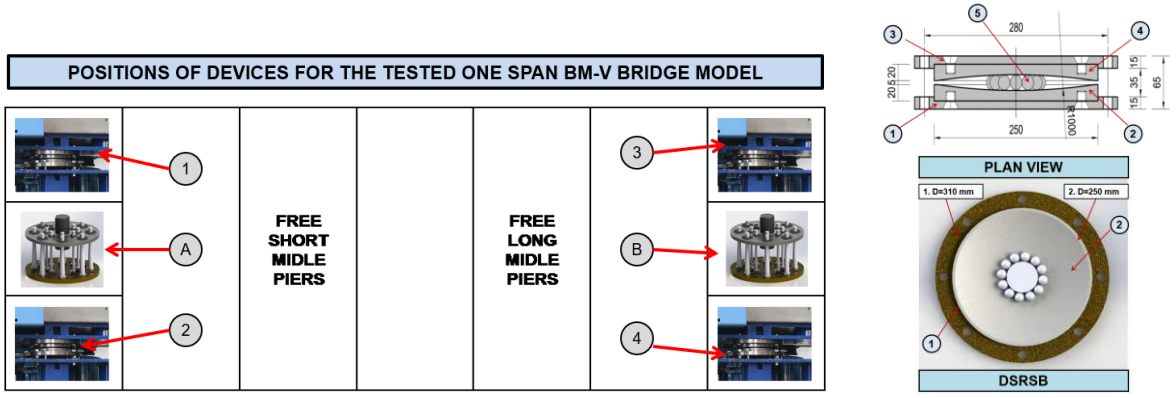


Figure 7 *Defined positions of DSRSB devices (1 to 4, with details right) and V-MG-ED devices (A and B) of the tested one-span large-scale USI-V-MG (BM-V) bridge prototype model on seismic shaking table*

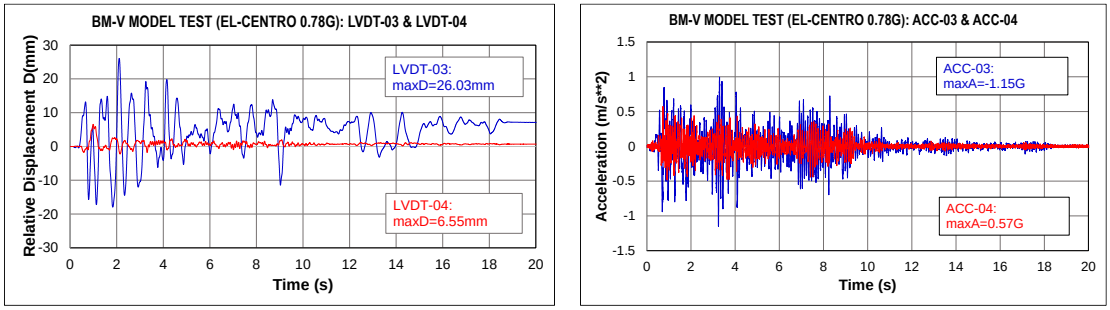


Figure 8 Relative superstructure displacement responses recorded by LVDT-03 & LVDT-04 (left) and acceleration responses recorded by ACC-03 & ACC-04 (right) during USI-V-MG (BM-V) shaking table bridge model test conducted with simulated strong El-Centro earthquake

7. Critical Seismic Shaking Table Tests Near Resonance of USI-V-MG Bridge Model

The ultimate goal of the present research includes development of advanced technology for seismic protection of bridge structures under extreme seismic loading. To realize the planed unique and scientifically important and specific experimental analysis of actual seismic response characteristics of innovatively assembled large-scale bridge model, with DSRSB isolation and new V-MG energy dissipation devices, under simulated the most critical near-resonance earthquake excitations, extensive well-focused shaking table tests have been planned and realized in study phase-III. However, to provide highly valuable comparative experimental data and full evidence in differences in seismic responses of innovative bridge model tested with different test options, two additional series of shaking table tests have been planned and conducted.

The first test series included initial shaking table tests of assembled bridge model with seismic isolation only, item 7.1 (phase-I). Initial tests actually represent the first basic experimental study, devoted to experimental testing of seismic response of assembled isolated-bridge prototype model, without installed energy dissipation (ED) devices, under simulated strong earthquakes. The second test series included shaking table tests of innovatively-upgraded isolated bridge model, item 7.2 (phase-II). The conducted tests actually represent experimental study of real seismic response characteristics of constructed innovatively-upgraded isolated bridge prototype model, existing with seismic isolation (SI) and new energy dissipation (ED) devices, under simulated strong earthquakes. Finally, regarding the obtained large set of experimental results, the effects of critical near resonance (NR) earthquake input on innovatively-upgraded isolated bridge model was made possible, item 7.4 (phase-IV. Actually, the study phase-IV was devoted to processing and comparative presentation of extreme seismic responses of innovatively-upgraded isolated bridge model considering the obtained results from conducted shaking table test under simulated two series of seismic input: (1) seismic input representing critical near resonance (NR) earthquake excitations of Phase-III and (2) seismic input representing selected location representative (LR) strong earthquake excitations of Phase-II. As stated above, approximately 5 million numerical values were recorded in each single test. With newly realized four original tests of phase-I and four original tests of phase-IV, additional large experimental data volume, containing about 40 million numerical values, have been recorded, processed and analyzed. Regarding the conducted very extensive experimental study program, including successfully realized full set of 16 original experimental tests, recorded were and processed about 80.000.000 numerical data values.

7.1. Phase-I: Initial shaking table tests of bridge model with isolation only

Study phase-I represent conducted initial experimental study devoted to experimental seismic response testing of constructed isolated bridge prototype model without ED devices under simulated strong earthquakes.

For the purposes of getting insight into contribution of the EDDs to the structural response, bridge model setup which involved only four DSRSB isolators (no SB dissipaters) has been tested on the

shaking platform under compressed El Centro excitation scaled to PGA 0.78g. The relative displacements recorded by LVDT-03 for the system with and without SB energy dissipaters are shown in Table. 2. By comparing two responses, it may be noticed that use of dissipaters reduced maximum displacement from 40.77mm to 26.03mm, or 56.62%. Such favourable contribution of EDD, adequately designed in their mech. properties, gain in importance for much stronger earthquakes.

Table 2 Recorded difference in peak relative displacements during shaking table test of BM2-V1 bridge model with ED devices [1c] and BM2 bridge model without ED devices [1c], under simulated **compressed** El-Centro earthquake*

Tests	**Test with ED devices [1c]**			**Test without ED devices [1c*]**		
	[1c] O-T1: C-El-Centro, PGA=0.78G			[1c*] O-T1: C-El-Centro, PGA=0.78G		
[1c&1c*]	Channel	MaxD (mm)	MaxD (%)	Channel	MaxD (mm)	MaxD (%)
diff.	LVDT-03	26.03	100.00	LVDT-03	40.77	**+56.62**

7.2. Phase-II: Shaking table tests of innovatively-upgraded isolated bridge model

Study phase-II represent experimental study devoted to seismic response testing of constructed innovatively-upgraded isolated bridge prototype model with seismic isolation (SI) and energy dissipation (ED) devices under simulated strong earthquakes.

Regarding the stated objectives, conducted were extreme-loading experimental tests of innovatively-upgraded isolated bridge with new V-MG ED devices, simulating the following four representative and strong compressed earthquakes: [1c] El-Centro, PGA=0.78G, [2c] Petrovac, PGA=0.72G, [3c] Landers, PGA=0.76G, and [4c] Northridge, PGA=0.89G, earthquake Table 3. The peak relative displacements recorded by LVDT-03 of the system upgraded with SB energy dissipaters are well controlled in all cases. Regarding peak responses, it may be noticed that use of dissipaters reduced maximum displacements to 26.03mm, 26.61mm, 20.35mm and 31.61mm, respectively.

*Table 3 Recorded peak relative displacements by LVDT sensors during conducted original shaking table tests of BM2-V1 bridge prototype model simulating **compressed**: [1] El-Centro, [2] Petrovac, [3] Landers and [4] Northridge earthquake*

Tests	**[1c]** O-T1: **C**-El-Centro, **PGA=0.78G**			**[2c]** O-T2: **C**-Petrovac, **PGA=0.72G**		
[1c&2c]	Channel	MaxD (-) (mm)	MaxD (+) (mm)	Channel	MaxD (-) (mm)	MaxD (+) (mm)
recorded	LVDT-03	-17.96	**26.03**	LVDT-03	**-26.61**	15.21
Tests	**[3c]** O-T1: **C**-Landers, **PGA=0.76G**			**[4c]** O-T2: **C**-Northridge, **PGA=0.89G**		
[3c&4c]	Channel	MaxD (-) (mm)	MaxD (+) (mm)	Channel	MaxD (-) (mm)	MaxD (+) (mm)
recorded	LVDT-03	**-20.35**	11.76	LVDT-03	-29.93	**31.61**

The observed favourable contribution of energy dissipation devices, provided reduction of maximum displacement bellow designed displacement limit of seismic isolators, amounting to 40.00mm. This reduction is gaining even higher importance for the case of bridge structures exposed to much stronger earthquakes.

7.3. Phase-III: Critical shaking table tests of innovatively-upgraded isolated bridge model

Study phase-III represent experimental study devoted to seismic response testing of constructed innovatively-upgraded isolated bridge prototype model with seismic isolation (SI) and ED devices under simulated critical near resonance (NR) earthquake input.

Realized model testing with compressed real earthquakes actually represent simulation of real seismic input regarding actual properties of designed and constructed scaled-model of bridge prototype, directly resulting from model similarity conditions. Frequency content of input records was accordingly changed. It is well demonstrated by presented acceleration response spectra for *compressed* Petrovac earthquake record with new frequency content used for testing, Figure 9. Dominant frequency domain includes periods less than 0.32s, while for periods T ≥ 0.32s, frequency domain is not significant.

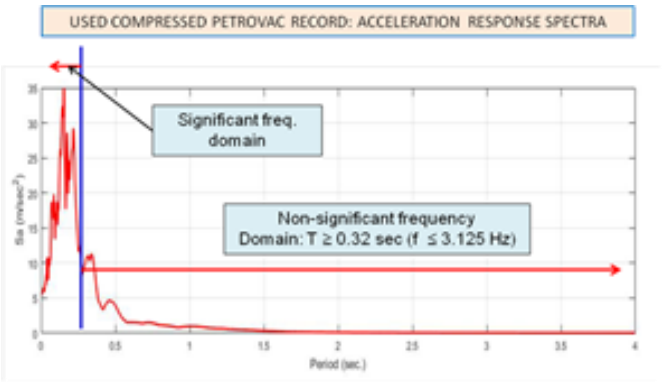


Figure 9 *Acceleration response spectra of **compressed** Petrovac record with new frequency content used for testing*

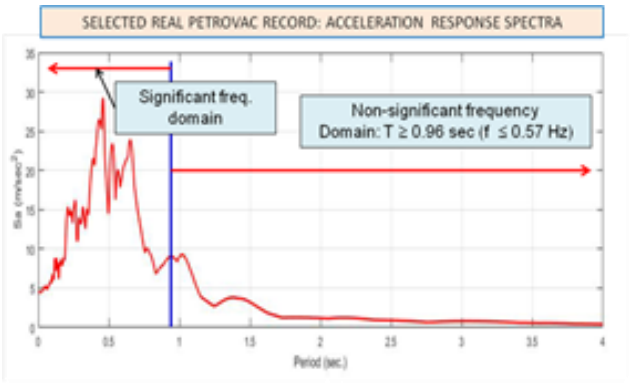


Figure 10 *Acceleration response spectra of **real** (not time compressed) Petrovac record representing actual frequency content*

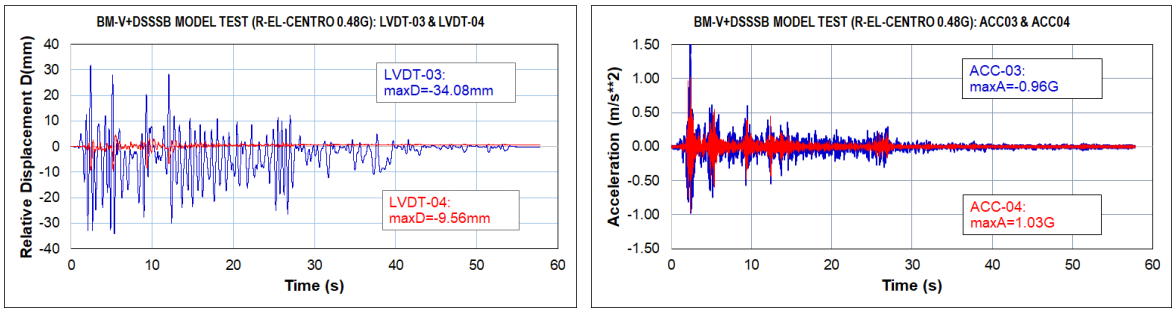


Figure 11 *Relative superstructure displacement responses recorded by LVDT-03 & LVDT-04 (left) and acceleration responses recorded by ACC-03 & ACC-04 (right) during USI-V-MG (BM-V) shaking table bridge model test conducted with simulated **real** El-Centro earthquake*

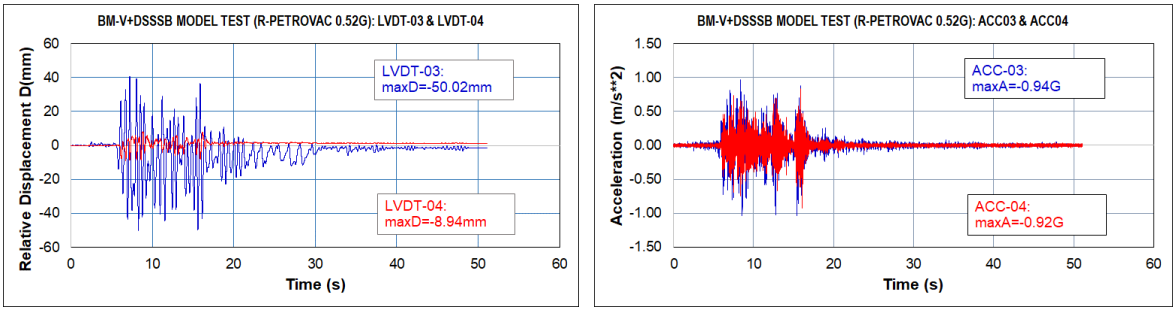


Figure 12 *Relative superstructure displacement responses recorded by LVDT-03 & LVDT-04 (left) and acceleration responses recorded by ACC-03 & ACC-04 (right) during USI-V-MG (BM-V) shaking table bridge model test conducted with simulated **real** Petrovac earthquake*

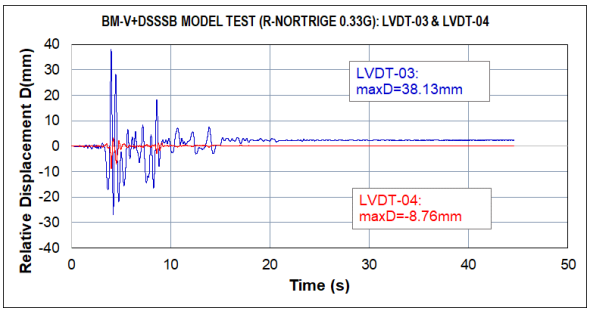


Figure 13 *Relative displacement response recorded by LVDT-03 & LVDT-04 during shaking table bridge model test with simulated **real** Petrovac earthquake*

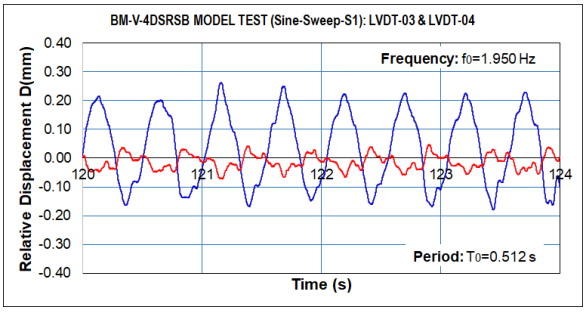


Figure 14 *Vibration period of bridge model **with seismic isolation only** defined using recorded relative displacement during shaking table sine-sweep test*

In Figure 14, shown is defined much larger initial vibration period of bridge model, T=0.512s, showing that dominant frequency content of seismic input was very well and significantly avoided. Initial vibration period was defined based on recorded time history of relative displacement during conducted initial sine-sweep shaking table test. Due to very small vibration amplitudes and present initial gaps, the excited model vibration actually corresponds to initial state with activated seismic isolation only.

The final experimental study included specific near resonance (NR) testing of constructed innovatively-upgraded isolated bridge prototype model with seismic isolation (SI) and energy dissipation (ED) devices, characterized by initial vibration period T=0.512s. Selection of applicable critical near resonance (NR) input was made after analysing acceleration response spectra of used real *(not time compressed)* earthquakes. Regarding, for example, acceleration response spectra of real Petrovac record, Figure 10, dominant frequency content is mainly distributed near fundamental period of the system. Due to similar observations for other earthquakes, the same four real earthquake records were accepted to be actual critical near resonance (NR) seismic input for shaking table tests.

Considering the stated critical test conditions, conducted were critical NR loading experimental tests of innovatively-upgraded isolated bridge with new V-MG energy dissipation (ED) devices, simulating the following four representative and strong real earthquakes: [1r] El-Centro, PGA=0.48G, [2r] Petrovac,

PGA=0.52G, [3r] Landers, PGA=0.76G, and [4r] Northridge, PGA=0.33G, earthquake Table 4. The peak relative displacements recorded by LVDT-03 of the system upgraded with SB energy dissipaters are considerably larger in all cases due to NR earthquake input. Regarding peak responses, it may be noticed that with present dissipaters maximum displacements are 34.08mm, 50.02mm, 40.55mm and 38.13mm, respectively.

*Table 4 Recorded peak relative displacements by LVDT sensors during conducted four original shaking table tests of BM2-V1 bridge prototype model simulating **real** [1] El-Centro, [2] Petrovac, [3] Landers and [4] Northridge earthquake*

Tests	**[1r]** O-T1: **R**-El-Centro, **PGA=0.48G**			**[2r]** O-T2: **R**-Petrovac, **PGA=0.52G**		
[1r&2r]	Channel	MaxD (-) (mm)	MaxD (+) (mm)	Channel	MaxD (-) (mm)	MaxD (+) (mm)
recorded	LVDT-03	**-34.08**	31.92	LVDT-03	**-50.02**	40.69
Tests	**[3r]** O-T1: **R**-Landers, **PGA=0.76G**			**[4r]** O-T2: **R**-Northridge, **PGA=0.33G**		
[3r&4r]	Channel	MaxD (-) (mm)	MaxD (+) (mm)	Channel	MaxD (-) (mm)	MaxD (+) (mm)
recorded	LVDT-03	**-40.55**	40.11	LVDT-03	-26.90	**38.13**

In Fig. 11. and Fig. 12. presented are relative superstructure displacement responses recorded by LVDT-03 & LVDT-04 (left) and acceleration responses recorded by ACC-03 & ACC-04 (right) during USI-V-MG (BM-V) shaking table bridge model test conducted with simulated **real** El-Centro and Petrovac earthquake, respectively.

In Fig. 13 presented is relative displacement response recorded by LVDT-03 & LVDT-04 during shaking table bridge model test with simulated **real** Petrovac earthquake

7.4. Phase-IV: Effects of critical near resonance (NR) earthquake input on innovatively-upgraded isolated bridge model

Study phase-IV was devoted to processing and comparative presentation of extreme seismic responses of innovatively-upgraded isolated bridge model considering the obtained results from conducted shaking table test under simulated two series of seismic input: (1) considered critical near resonance (NR) earthquake input of Phase-III and (2) selected location representative (LR) strong earthquakes of Phase-II.

In Table 5. Comparatively are presented recorded peak relative displacements by LVDT sensors during conducted original shaking table tests of BM2-V1 bridge prototype model simulating both, *real and compressed* [1] El-Centro, [2] Petrovac, [3] Landers and [4] Northridge earthquake. To show actual effects of frequency content of NR earthquake input, comparative values of peak relative displacements for the case of seismic tests with compressed earthquakes are shown for the same PGA levels.

In all four comparative test cases, much larger peak values of relative displacements were recorded during realized tests with simulated critical NR earthquake input. The recorded increase of peak response reached amounts of +112.86% for El-Centro, +160.38% for Petrovac, +99.26% for Landers and +225.34% for Northridge earthquake, Table. 5.

The presented results clearly pointed out the following highly important observations: (1) Seismic isolation only may be regarded as unsafe solution for bridges exposed to strong earthquakes; (2) The new V-MG energy dissipation device represent very efficient solution for seismic upgrading of isolated bridges exposed to very strong earthquakes and (3) The possible negative effects of critical NR seismic input should be avoided through application of effective design process of seismically upgraded isolated bridges with new V-MG-ED devices.

*Table 5 Recorded peak relative displacements by LVDT sensors during conducted original shaking table tests of BM2-V1 bridge prototype model simulating **real and compressed** [1] El-Centro, [2] Petrovac, [3] Landers and [4] Northridge earthquake*

No. 1	[1r] O-T1: **R**-El-Centro, **PGA=0.48G**			[1c] O-T1: **C**-El-Centro, **PGA=0.48G**		
[1r&1c]	Channel	MaxD (mm)	MaxD (%)	Channel	MaxD (mm)	MaxD (%)
diff.	LVDT-03	34.08	**+112.86**	LVDT-03	16.01	100.00
No. 2	[2r] O-T2: **R**-Petrovac, **PGA=0.52G**			[2c] O-T2: **C**-Petrovac, **PGA=0.52G**		
[2r&2c]	Channel	MaxD (mm)	MaxD (%)	Channel	MaxD (mm)	MaxD (%)
diff.	LVDT-03	50.02	**+160.38**	LVDT-03	19.21	100.00
No. 3	[3r] O-T3: **R**-Landers, **PGA=0.76G**			[3c] O-T3: **C**-Landers, **PGA=0.76G**		
[3r&3c]	Channel	MaxD (mm)	MaxD (%)	Channel	MaxD (mm)	MaxD (%)
diff.	LVDT-03	40.55	**+99.26**	LVDT-03	20.35	100.00
No. 4	[4r] O-T4: **R**-Northridge, **PGA=0.33G**			[4c] O-T4: **C**-Northridge, **PGA=0.33G**		
[4r&4c]	Channel	MaxD (mm)	MaxD (%)	Channel	MaxD (mm)	MaxD (%)
diff.	LVDT-03	38.13	**+225.34**	LVDT-03	11.72	100.00

8. Conclusions

Based on research results obtained from the conducted extensive experimental and theoretical studies using designed innovative USI-V-MG bridge model prototype, the following main conclusions are derived:

1. The constructed and investigated novel DSRSB seismic isolation devices are very attractive and effective passive devices for seismic vibration isolation of bridges in arbitrary direction;
2. The new vertical multi-gap multi-directional hysteretic V-MG energy dissipation devices possess unique energy absorption features since they are capable of adapting their stable behaviour to the arbitrary earthquake direction and to the actual level of seismic input energy. The new V-MG energy dissipation devices provided innovative, very stable and advanced 3D hysteretic response in the most critical cases of repeated strong earthquake effects in all directions;
3. The displacement limiting devices, DLD, represent very effective obligatory measure in function of the last line of defence from excessive displacements of the bridge superstructure. DLD actually represent efficient passive system providing improvement of the bridge seismic safety with eventual activation only in critical cases of very strong earthquakes;
4. With the results from the conducted experimental tests confirmed is that the new USI-V-MG system represents the upgraded high performance seismic isolation option for bridges. The system is created based on optimized seismic energy balance and represents effective technical innovation capable of integrating the advantages of seismic isolation, seismic energy dissipation and effective displacement control. The developed and tested USI-V-MG system shows very high seismic response modification performances and could be used for efficient seismic protection of bridges in all directions under the effect of very strong repeated earthquakes; and
5. During the further study phases, creative analytical research and simulation activities will be carried out, specifically directed to development of practical design rules of the developed new seismically safe USI-V-MG bridge system.

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Influence of Concrete Cover Thickness on Fire Resistance of RC Beams According to EUROCODE 2

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Abstract:

A parametric analysis of two span continuous reinforced concrete beam exposed to standard ISO 834 fire curve is presented in this paper. The influence of the concrete cover thickness on the fire resistance of the beam exposed to fire only from three sides is analyzed.
The analysis of the reinforced concrete beam is conducted by using the Reduced Cross Section method, given in Eurocode 2-1-2. Temperature dependent mechanical and thermal properties of the constructive materials (concrete and steel) are adopted according to the recommendations given in Eurocode 2-1-2.
The analysis has shown that the concrete cover thickness has minimum positive effect on the fire resistance of the analyzed RC beam and this is due to the larger concrete cover thickness and based on this the temperature penetration is slower. The concrete temperature in the middle of the section and the reinforcement temperature are slightly lower, consequently a higher fire resistance is achieved.
Based on the results of the conducted analysis the behavior of the reinforced concrete beam exposed to fire has been defined and recommendations for increasing the fire resistance are given.

Keywords: *Continuous RC beam; Concrete cover thickness; Standard fire curve; Thermal analysis; Fire resistance*

1. Introduction

The subject of this paper is the analysis of the impact of fire on continuous reinforced concrete beams as structural elements of buildings. The influence of the concrete cover thickness on the fire resistance of the beam is analyzed. The analysis are carried out on continuous reinforced concrete beams loaded with constant distributed loads, exposed to the fire from three sides during the time: R60, R90, R180 and R240.

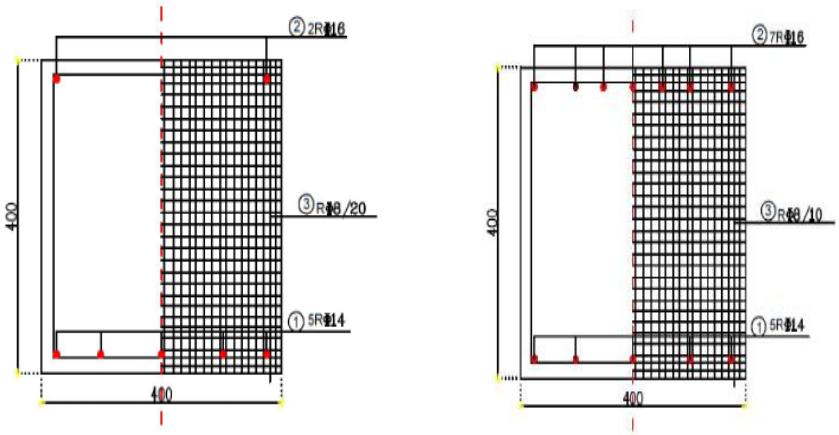
The main objective of this paper is to define data on impact of analyzed parameters on the fire resistance of continuous reinforced concrete beams. When designing constructions for ambient temperature, these data should be taken as appropriate measures for ensuring greater fire resistance and better fire safety of buildings. The parametric analysis of continuous reinforced concrete beams was performed using the Method of Reduced Cross Section, according to Eurocode 2-1-2 [5]. The analyses were performed for continuous reinforced concrete beam with dimensions 40x40 cm with concrete cover thickness a = 2.5 cm in the first case and concrete cover thickness a = 3 cm in the second case. The rise of temperature in the fire sector over time is defined by the standard fire ISO 834.

Temperature dependent mechanical and thermal properies of constructive materials (concrete and steel) have been adopted in accordance with the recommendations given in Eurocode 2-1-2, which also provides the design procedures for the approximate calculation on fire resistance of structural elements.

2. Comparative Analysis on Fire Resistance of RC Beams According to Eurocode 2

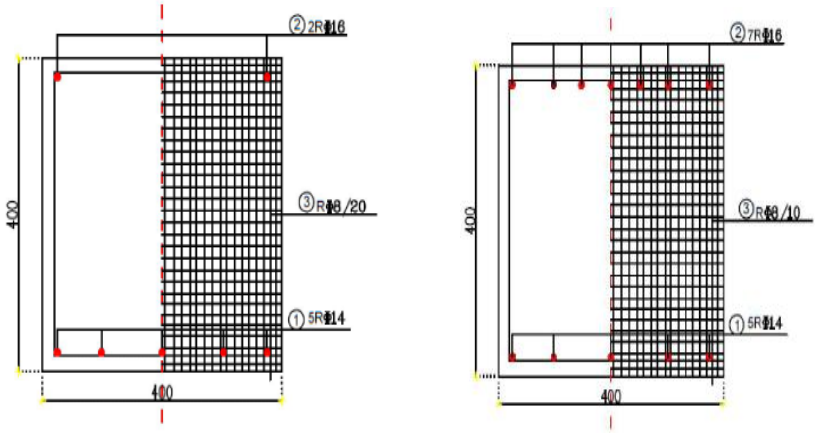
The influence of the concrete cover thickness on the fire resistance of continuous reinforced concrete beam with spans 2 x 5 = 10 m is analyzed. The first case is when the cross-section is 40x40 cm with concrete cover thickness a = 2.5 cm, while the second case is when the cross-section is 40x40 cm with concrete cover thickness a = 3 cm. In both cases, the beam is exposed to a permanent load of 20 kN / m ' and a variable load of 10 kN / m'.

According to the calculations carried out for a 40x40 cm cross section, with different concrete cover thickness, 5ϕ14 were adopted as the main positive reinforcement in the bottom part of the cross section, and 2ϕ16 were adopted in the top zone along the whole span, while 5ϕ16 bars were added as negative reinforcement above the internal support (Figure 1 and Figure 2). According to the recommendations for providing greater fire resistance, 20% of the main reinforcement over the supports should be extended along the span, and for this reason the longitudinal reinforcement in the top zone have been adopted to be 2ϕ16.



a) cross section along the span b) cross section above the support

Figure 1 *Cross section of continuous reinforced concrete beam in the middle of the span and above the support, for cross section 40x40 cm with cover thickness a = 2.5 cm*



a) cross section in the field b) cross section above the support

Figure 2 *Cross section of continuous reinforced concrete beam in the middle of the span and above the support, for cross section 40x40 cm with cover thickness a = 3 cm*

According to the calculations carried out by using the Reduced Cross Section Method given in Eurocode 2, Part 1-2 [5], for the cross section 40x40 cm with concrete cover thickness a = 2.5 cm , the beam failure is reached after 105 min., while for the cross section 40x40 cm with concrete cover thickness a = 3 cm, it is achieved after **111 min.**. It means that the fire resistance of the first beam is **105 min.** and of the second one is 111 min. According to Eurocodes, both beams have fire resistance R90. For the both cross-sections, the steel temperature for the bottom reinforcement is taken from the isotherms given in [2], which refer to a certain time of fire exposure.

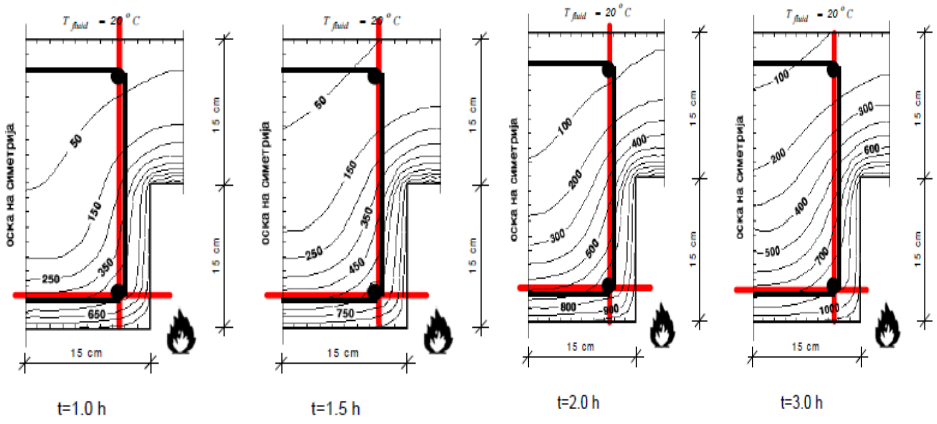


Figure 3 *Time development of isotherms in the cross section of RC beam with dimensions 40x40 cm and concrete cover thickness a = 2.5 cm, exposed to ISO 834 fire curve from the bottom side*

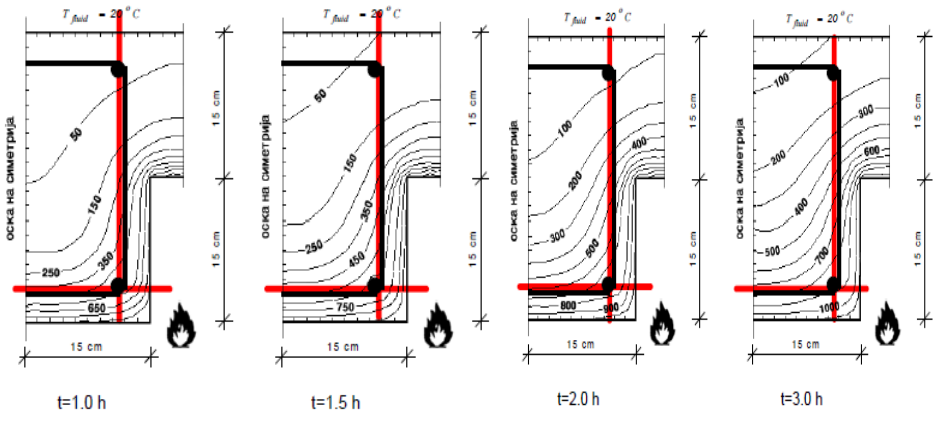


Figure 4 *Time development of isotherms in the cross section of RC beam with dimensions 40x40 cm and concrete cover thickness a = 3 cm, exposed to ISO 834 fire curve from the bottom side*

The temperature values for the steel elements 1, 2 and 3, defined according to the isotherms for a particular time, are shown in Table 1. The results show that the temperature in the steel elements differ due to the greater concrete cover thickness of the cross section 40x40 cm.

Accoding to the Reduced Cross Section Method, for given fire resistance: R60, R90, R120 and R180, the load bearing capacity for positive and negative moments is defined and compared with the bending moments coused by the permanent and variable loads for fire situation. For the beam with cross sections 40x40 cm, with different concrete cover thickness, the time dependent bending moments at the mid span and over the internal support are defined and presented in Figure 5 and Figure 6, respectively. According to the presented results it is obvious that, as a result of high temperatures, the load bearing capacity of the RC beams is reduced in time. At the moment when the bending moment at the support, or at the mid span, will be equal to the bearing capacity of the cross section, the failure occurs.

Table 1 *Temperature of steel elements according to isotherms given in Eurocode 2, for cross sections 40x40 cm with concrete cover thickness a = 2.5 cm and cross section 40x40 cm with concrete cover thickness a = 3 cm*

Eurocode 2, cross section 40x40 cm with concrete cover thickness a = 2.5 cm			Eurocode 2, cross section 40x40 cm with concrete cover thickness a = 3 cm		
Time (min)	Element	Temperature (°C)	Time (min)	Element	Temperature (°C)
60	1	350	60	1	350
	2	350		2	350
	3	600		3	550
90	1	550	90	1	550
	2	550		2	550
	3	700		3	650
120	1	550	120	1	550
	2	550		2	550
	3	800		3	750

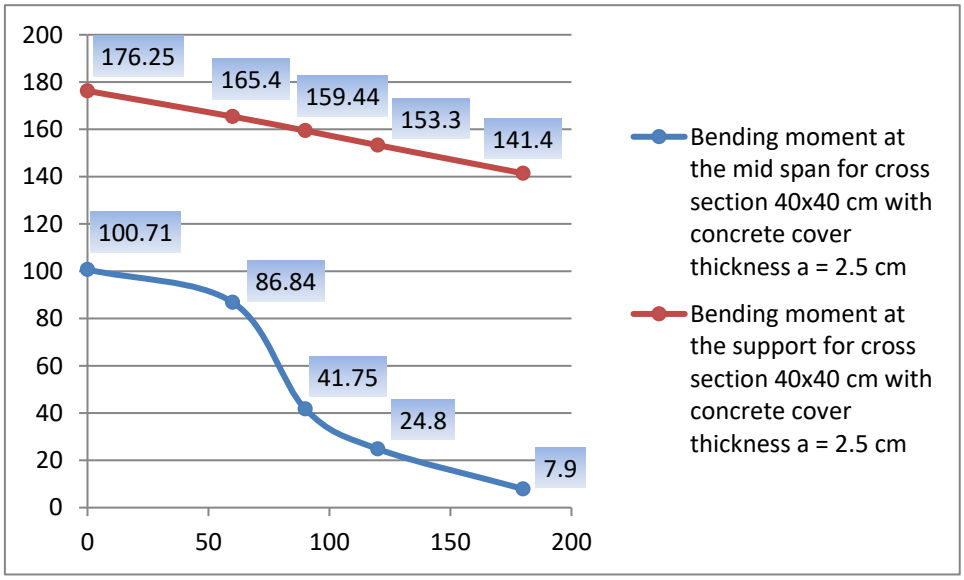


Figure 5 *Load bearing capacity of the RC beams with cross section 40x40 cm and concrete cover thickness a=2.5 cm, for time 60, 90, 120 and 180 min*

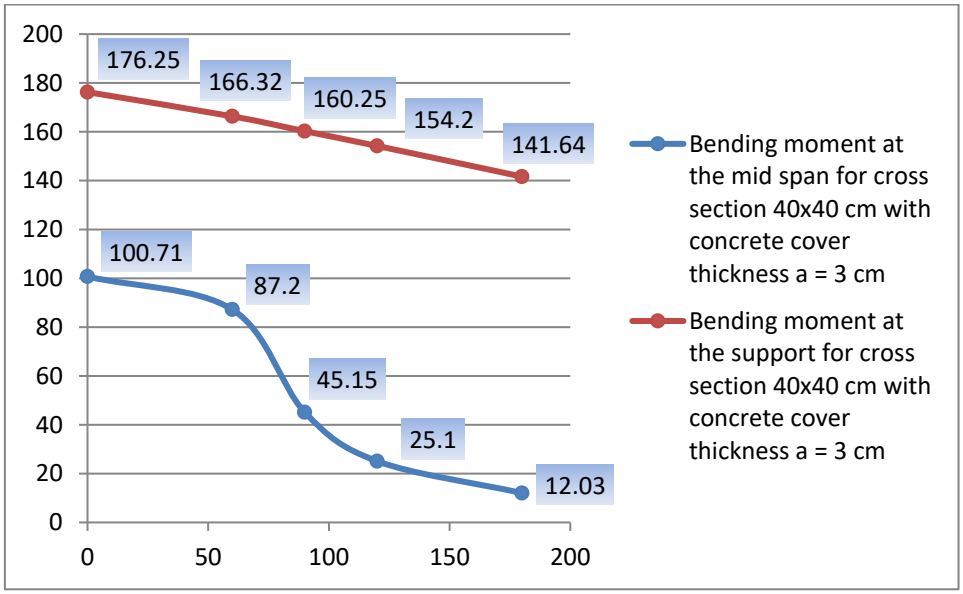


Figure 6 *Load bearing capacity of the RC beams with cross section 40x40 cm and concrete cover thickness a=3 cm, for time 60, 90, 120 and 180 min*

The diagrams show a small difference in the results for the bearing capacity of both beams at mid span and at the support. For cross section 40x40 cm with concrete cover thickness a = 2.5cm, at time t = 90 min, the bearing capacity for sagging moment in the mid span is $\mathbf{M^{+} = 41{,}75\ kNm}$, and bearing capacity for hogging moment at the support is $\mathbf{M^{-} = 127{,}5\ kNm}$, while for the cross section 40x40 cm with concrete cover thickness a = 3 cm, the bearing capacity for sagging moment in the mid span and bearing capacity for hogging moment at the support are: $\mathbf{M^{+} = 45{,}15\ kNm}$, and $\mathbf{M^{-} = 112{,}5\ kNm}$, respectively. The small difference in the obtained results is due to the greater concrete cover thickness of the cross section 40x40 cm.

Table 2 presents the values for the load bearing capacity at the mid span and at the support for different times of fire action, for the cross sections with different concrete cover thickness.

Table 2 *Load bearing capacity at the mid span and at the support, according to Reduced Cross Section Method given in Eurocode 2, for cross sections 40/40 cm with concrete cover thickness a = 2.5 cm and cross section 40/40 cm with concrete cover thickness a = 3 cm*

Eurocode 2, cross section 40x40 cm with concrete cover thickness a = 2.5 cm			Eurocode 2, cross section 40x40 cm with concrete cover thickness a = 3 cm		
Time (min)	Bending moment at mid span (kNm)	Bending moment at the internal support (kNm)	Time (min)	Bending moment at mid span (kNm)	Bending moment at the internal support (kNm)
60	86.84	165.4	60	87.2	166.32
90	41.75	159.44	90	45.15	160.25
120	24.8	153.3	120	25.1	154.2
180	7.9	141.4	180	12.03	141.64

The sagging moment at mid span exceeds the cross section bearing capacity after 90 minutes of fire exposure and this effect causes redistribution of the bending moment diagram and the negative momentum above the support is increased. The values for the redistributed bending moments at the support, for the beams with cross sections 40x40 cm and concrete cover thickness a = 2.5 cm in the first case and a = 3 cm in the second case, are shown in Figure 7 and Figure 8, respectively.

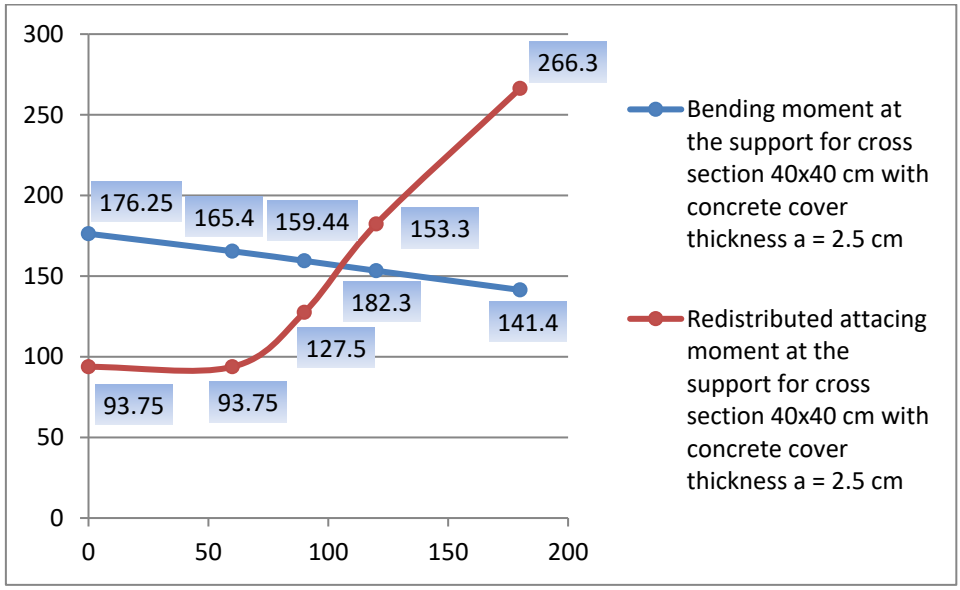


Figure 7 *Load bearing capacity and redistribution of the bending moments at the support for the beams with cross section 40x40 cm and concrete cover thickness a=2.5 cm*

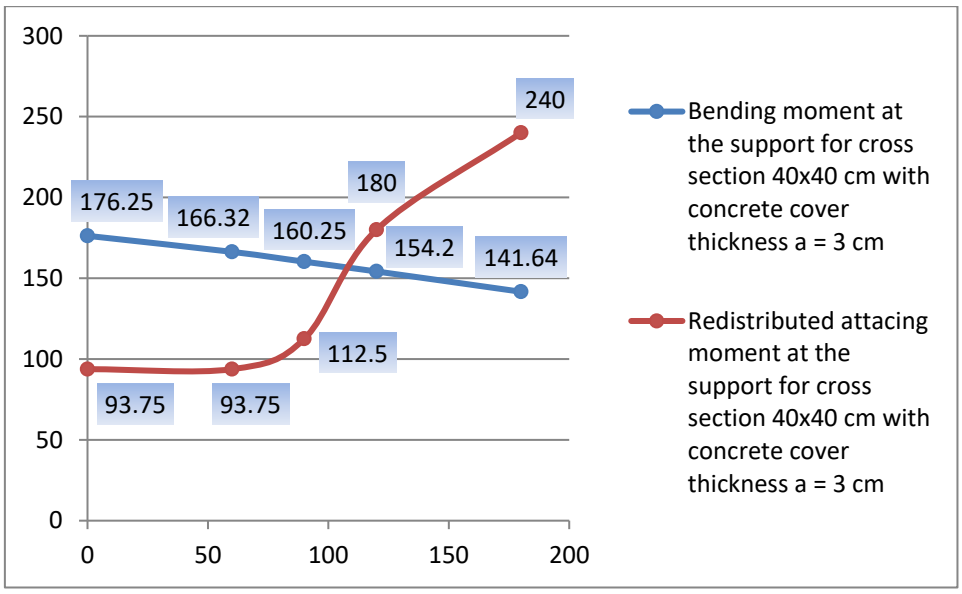


Figure 8 *Load bearing capacity and redistribution of the bending moments at the support for the beams with cross section 40x40 cm and concrete cover thickness a=3 cm*

According to the analyses for the beam with cross section 40x40 cm with concrete cover thickness a = 2.5 cm, the plastic hinge in the middle of the span occurs after 90 minutes of standard fire action, and from that moment the redistribution of bending moments starts. From the presented diagrams it can be seen that at the moment **t=90 min.** the negative moment at the support is **M^- = 127,5 kNm**, but after **15 min** (t = 105 min) the cross section does not accept the redistributed moment, resulting in a plastic hinge at the support and the beam failure occurs. According to Eurocode 2-1-2, the fire resistance of the beam is **R90**.

According to the analyses for the beam with cross section 40x40 cm, the plastic hinge in the middle of the span occurs after 90 minutes of standard fire action, and from that moment the redistribution of bending moments starts. The negative moment at the support after 90 min. of fire action is **M^- = 112,5 kNm**. A plastic hinge is formed **21 minutes** later (t = 111 min), and beam failure occurs. Although the failure of the second beam occurs later than for the first beam, according to Eurocode 2-1-2, the fire resistance of the beam is **R90**, too.

Table 3 shows the values of the redistributed bending moments at the support, for the two cross sections, for different time of fire exposure.

Table 3 Redistribution of bending moments at the support, for cross section 40x40 cm with concrete cover thickness a = 2.5 cm and cross section 40x40 cm with concrete cover thickness a = 3 cm

Cross section 40x40 cm with concrete cover thickness a = 2.5 cm		Cross section 40x40 cm with concrete cover thickness a = 3 cm	
Time (min)	Redistributed moment at the support (kNm)	Time (min)	Redistributed moment at the support (kNm)
0	93.75	0	93.75
60	93.75	60	93.75
90	127.5	90	112.5
120	182.3	120	180
180	266.3	180	240

3. Conclusions and Recommendations

Fire resistance of continuous reinforced concrete beams, depends on: geometrical characteristics of the beams, temperature dependent mechanical and thermal properties of the materials, concrete cover thickness, steel ratio and fire scenario. Dimensions of the cross sections play an important role in determining the fire resistance of the beams.

Continuous reinforced concrete beam with cross-section dimensions 40x40 cm, with different concrete cover thickness and permanent load "q", is analyzed and the fire resistance is defined. The Reduced Cross Section Method, given in EN1992-1-2 is used, and the results are compared.

The analyses showed that the concrete cover thickness of the cross section of the beam has a small positive effect on its fire resistance. In case of wider beam the fire resistance is little higher due to the slower temperature penetration into the beam cross section. In case of fire exposed beam from three sides, the concrete cover thickness of the beam is expected to have much better effect. This problem will be investigated in future.

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Determination of Automobile Speed Violation Intensity Areas in Turkey

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Abstract:

With the development of the transportation sector in the world, high-speed cars are developing. In addition, the development of highways also enables faster and more comfortable transportation. Due to these developments, speed violation values have been increased considerably. But despite this, drivers are risking both their own lives and the lives of others by violating speed. In order to prevent this situation, it is necessary to take measures to reduce the speed violation. In this study, speed violation data on state roads in Turkey were classified using data mining algorithms. Later, these classification data were analyzed in ARCGIS software and the places with the highest speed violation density were determined. This study provides an important benefit for policy makers. Because it has been revealed that it would be more beneficial to increase speed violation inspections in which regions.

Keywords: *Speed violation; Density map; State roads*

1. Introduction

Road transport is the most common type of transport. For this reason, road transportation networks are developing day by day and high-quality roads are being built. Also, with the development of technology and smart transportation systems, road vehicles with high technological features and fast access are being produced. Most drivers openly admit that they more or less regularly exceed the speed limit. They state the reasons for these intentional speed limit violations as follows: they were in a hurry, they generally enjoy driving fast and they were bored (Elvik et al., 2004).

Speed violations can cause various traffic problems. The biggest of these problems is traffic accidents. Major accidents can occur, causing material and moral damages. Besides, since these vehicles have high weights, it becomes difficult for the drivers to control the vehicle at speeds above the specified level (Anastasopoulos and Mannering, 2016). Among road vehicles, light vehicles can reach much higher speeds than heavy vehicles. Due to this situation, the speed limits for light vehicles on highways are higher than for heavy vehicles. Among light vehicles, automobiles have the highest acceleration potential. The fact that automobiles can reach high speeds can cause speed violations to be more. Because drivers travel alone or with a few people in these vehicles. For this reason, they feel more comfortable than other vehicles. This situation can increase the drivers' desire to speed. The increase in the desire of the drivers to speed also causes speed violations. Speeding violations cause material and moral losses. It can cause very serious problems, especially as it causes serious injury or death (Kuşkapan et al., 2021).

There are various studies examining speed violations of vehicles. Afghari et al., (2018) analyzed the proportion of speed limit violations across highway segments using a panel mixed logit fractional split model. The results of the model suggested a tendency among drivers to commit minor speed limit violations irrespective of causal factors. Imaninasab et al., (2016) developed a prediction model using vehicles accident. Poisson regression and negative binomial regression models were employed for modeling purposes. After assessment of the models, factors including natural light condition, vehicles daily volume, speed limit violation and vehicle defects, especially in lighting system during darkness, were found to be the most effective factors on vehicle accidents. Saifizul et al., (2011) analyzed the effect of gross vehicle weight and category of vehicle on free-flow speed and their interactions using empirical statistical techniques. The study results showed that the current speed limit is relatively high for a vehicle with a GVW of over 20t. Therefore, the authors proposed a new concept of setting the speed limit for vehicles by incorporating the weight parameter.

In this study, speed violations by automobile drivers on state roads in Turkey were examined. These speed violation rates were analyzed by density using ArcGIS software. According to the results of the analysis, the cities with the highest speed violation rates in Turkey were revealed.

2. Material Method

2.1. Study area

Turkey is an important transit point between Asia and Europe. It is like a bridge between the two continents in passenger and freight transport. Approximately 90% of freight transportation and approximately 88% of passenger transportation in the country are provided by the highway. For this reason, the transportation network has a developed structure. As of 2020, there is about 31 thousand km of state roads in Turkey (General Directorate of Highways, 2020). State roads also play an important role in the transition between provinces. Speed limits are applied to ensure safe transportation on these roads. A map of the network of state roads in Turkey is given in Figure 1 below.

Figure 1 *Map of the network of state roads in Turkey*

2.2. Data processing

The General Directorate of Highways (GDH) is a state agency in charge of the construction and maintenance of all public roadways outside of cities and towns in Turkey. Also, it has activities such as improving and repairing the roads and keeping them under constant maintenance to ensure their safe use. Another important task is to collect, press and publish the information about activities of GDH. GDH publishes the annual average daily number of traffic (AADT) for all vehicle types passing through road sections in all provinces and speed violation rates for all vehicle types. Thanks to these data, it is easier to make traffic analyses. Highways in Turkey are divided into 17 regions with respect to their location. Data are calculated separately for these 17 regional directorates. Each regional directorate covers several cities. The data generated by the regional directorates include detailed information. It is possible to get down to the center of the problems thanks to the creation of data, especially considering the vehicle types.

2.3. Spatial analysis

Spatial analysis is sampling, manipulation, exploratory and confirmatory analysis of data into spatial modeling which encompasses a large and diverse set of models. IDW is one of the most widely used methods in spatial analysis. In the IDW interpolation, the cell values are determined by a linear weighted combination of the dataset of sample points. The weight represents a function of inverse distance (Nistor et al., 2020). The IDW interpolation assumes the proportionality of correlations and similarities between neighbors and the distance between them. The interpolated surface represents a locally dependent variable (Chen et al., 2018). In the standard IDW method, the height of the interpolation point at the P (x, y) position in the region covered by the N = {X, Y, Z} point set is calculated by the equation.

$$z_e = (\sum_{i=1}^{n} S_i * Z_i)/(\sum_{i=1}^{n} S_i) \quad (1)$$

In the equation, x, y, z denote the height value of the point, Z the height values of the fulcrums, S the weight values, n the number of fulcrum points. S weight values in Eq. (1) as a function of the distance (d) between the fulcrum point and the interpolation point is calculated from the equation.

$$Si = 1/d_p^i,\ i = 1, 2, 3, 4\ \ldots\ p = 1, 2, 3, 4 \quad (2)$$

As the value of the p power parameter is increased in the function, the effect of distant points on the calculation decreases in Eq. (2). In other words, it is aimed to minimize the negative effects in modeling the surface where the interpolation point of the data obtained from distant points is located (Shukla et al., 2020). The idea of stacking layers containing different kinds of data and comparing them with each

other on the basis of where things are located is the foundational concept of spatial analysis (Figure 2). The layers' interlock in the sense that they are all georeferenced to true geographic space (Arcgis, 2021).

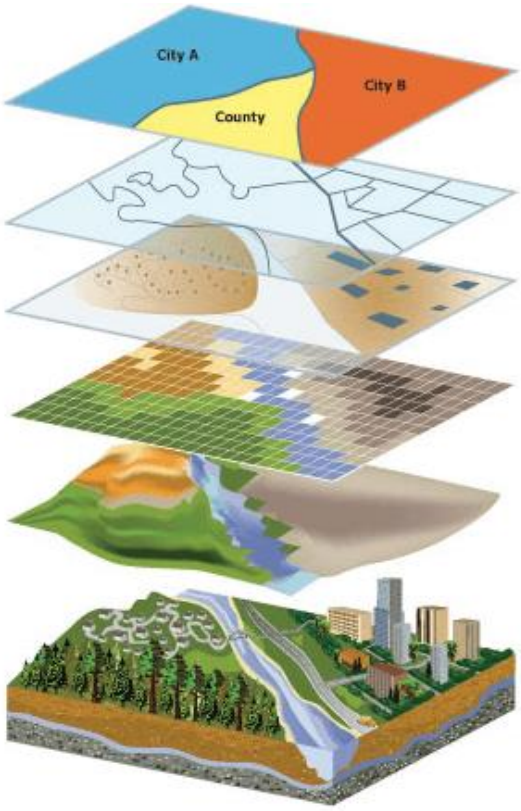

Figure 2 Geographic space layers in ArcGIS

3. Results and Discussions

AADT values of cities provide important information for vehicle densities. By using AADT values, transportation planning and road designs can be made. AADT values of cities in Turkey are given in Figure 3 below.

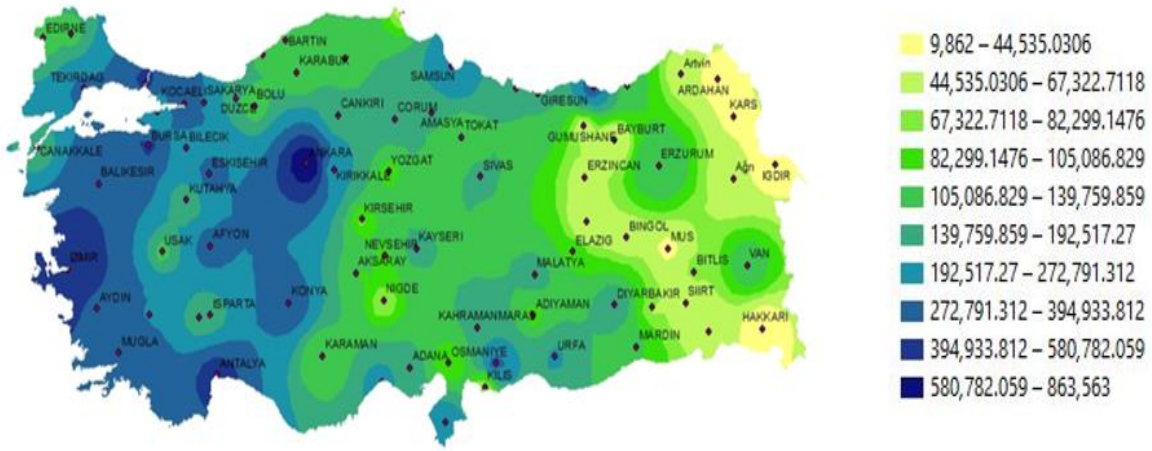

Figure 3 Annual average daily traffic

It is seen that AADT values are high in big cities such as Ankara, Istanbul, Izmir and Antalya. Because these cities have high population. Also, activity areas such as tourism, trade and education in these cities increase vehicle mobility. The high number of vehicles causes an increase in traffic density. In this case,

the movement areas of the drivers may be restricted. Thus, increasing their speed becomes more difficult. Therefore, speed violation rates may be lower in cities where AADT values are very high. Figure 4 below shows the map with the density of speed violations in the cities.

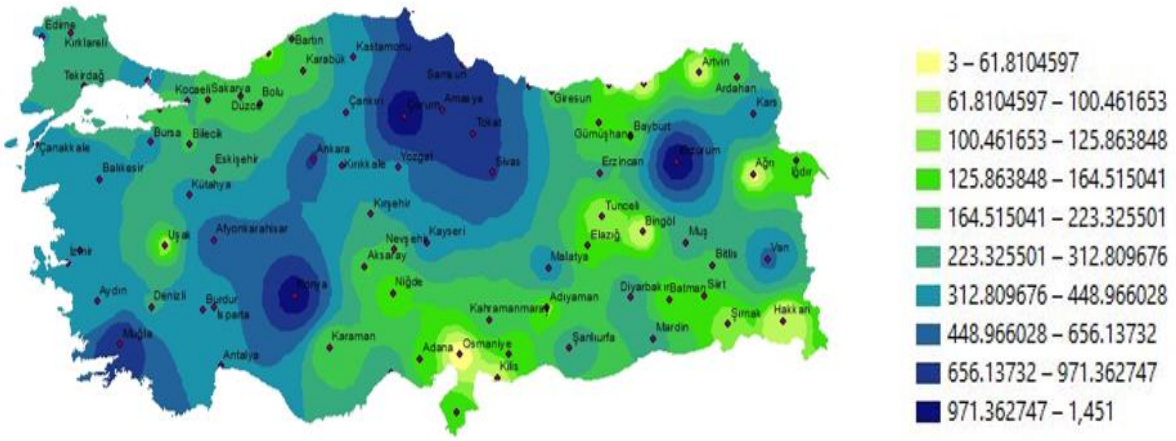

Figure 4 Speed violation rates

When the figure is examined, it is seen that speed violation rates are high in Erzurum, Konya and Çorum provinces. The common feature of these three cities is that they are located on important transit roads. In these cities, the high number of speed violations by cars can increase the number of accidents. Policy makers need to take some measures to reduce speeding violation rates in these cities. In particular, speed enforcement and enforcement of sanctions can significantly reduce speeding violations. In addition, drivers can be warned with the help of smart signs by instantaneously speed control with camera systems.

4. Conclusion

The following results were obtained with this study:

- Speed violation rates are quite high in Erzurum, Çorum and Konya provinces.
- Measures should be taken to reduce speed violations in these cities.
- Inspections can be increased in areas where speed violations are intense.
- Cameras with electronic detecting system can be installed to reduce speed violations.
- Speed violation rates are lower in cities such as Ankara, Istanbul, Izmir and Antalya, where the annual average daily traffic value is high.
- In cities where the annual average daily traffic value is high, multiple factors may be effective in the low rate of speeding violations. The most prominent of these factors are:
- Due to the high density of vehicles, suitable conditions for speeding may not occur.
- Again, speed controls may be excessive because the vehicle density is high.

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Inclined Aqueduct of Skopje: A History in Brief and Preparation for the Future

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Abstract:

One of the last remaining aqueducts on the Balkan Peninsula is located in Skopje, the capital of R. N. Macedonia. It stretches approximately 400 m in length and is about 6 m tall. Unfortunately, it has suffered great destruction, and two inclinations have appeared which threat its existence. In order to determine the reasons, historical and existing technical documents were reviewed, geotechnical drillings were conducted and exhaustive laboratory tests and office works were performed. It was found that the soil layers are heterogeneous, part of which having a very high swelling capacity. Also, the location is swampy and there are two tectonic rifts just underneath the aqueduct. Thus, it was necessary to prepare a project which will deal with these elements in order to supply permanent stabilization. Several different techniques were analyzed and compared from both a technical and economical aspect: enlarging the shallow foundations, applying large size reinforced concrete piles or installing steel self-drilling micro-piles. The presentation will digest the performed field and laboratory tests and the complex numerical analyses modelling the behavior of the aqueduct under the influence of the local devastating earthquakes and difficult soils, respecting the already weakened material in the above structure.

Keywords: *Aqueduct; Inclination; Swelling; Stabilization; Micro-piles*

1. Introduction

Water supply used to be a great issue facing humanity. During the Ancient and Middle ages, one of the ways to solve this problem was with construction of aqueducts: these monumental structures, built of stone, brick and mortar, transferred fresh water from capable sources in higher locations to large cities. One of the last remaining aqueducts on the Balkan Peninsula, built during the Ottoman Empire, is located in Skopje, with length of nearly 400 m and height of about 6 m.

Figure 1 View on the Skopje Aqueduct

Unfortunately, it has suffered destructions, and recently two inclinations have appeared: towards east at one section long 25 m, and towards west at other section with similar length. Their size is up to 60 cm, i.e. 10% of the height, which is tremendous and is threatening the existence of the aqueduct. In order to determine the reasons for such damages, review of historical and existing technical documentation was realized, geotechnical drillings have been conducted at the location, above- and underground structure conditions were mapped, soil samples were taken for exhaustive laboratory tests and office works were performed for selection of appropriate stabilization measure. It has been found that there are very heterogeneous soil layers beneath and along the structure, part of which have swelling capacity high enough to lift up the aqueduct. This is appropriate for the upper layers, which are quaternary sediments – clay and silt, while the deeper ones consist of sand and gravel, which, together with the swampy location, leads to great differential settlements. Also, Skopje has regularly suffered from very strong earthquakes in the past and moreover: two tectonic rifts were detected just under the aqueduct! Not to leave behind, the human factor is also included: four of the columns were ruined and reconstructed later because of military exercises, while having been built in the time of the Ottoman Empire, gullible people thought it was a good idea to dig for gold, around, under and in the columns.
As the pillars are continued in the ground same as above, there is no specific foundation construction of the Aqueduct. This might be other reason for the damages, where the most alarming is the serious eccentricity that the columns are confronting: more than 0.5 m for few of them. As mentioned above, what demands special attention are the size and direction of the current inclinations: one group of columns are inclined towards west, among which the most inclined is column C13, for 53 cm, while among those inclined towards east the most endangered is column C26, with 22 cm. Other challenges are the flow of underground water, which has undermined the pillars, and the very bad actual construction of the above part of the pillars

Figure 2 *Devastation after military exercises*

Figure 3 *Human factor in destroying the pillars of the Aqueduct*

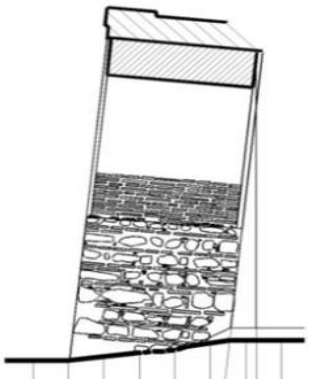

Figure 4 *Cross-section of inclined columns*

2. Numerical analyses

Thus, the project had to deal with these elements and to serve high quality, guaranteed and permanent stabilization. Several different techniques (enlarging the shallow foundations; applying large size reinforced concrete piles; installing steel self-drilling micro-piles) have been analyzed in software based on Finite Elements Method (FEM) modelling the behavior of the aqueduct (separately with each stabilization measure) under the influence of the local devastating earthquakes and difficult soils, respecting, of course, the already weakened material in the above structure, and compared from technical and economical aspect. The numerical analyses are described below.

2.1. Numerical modelling in ROBOT

Considering the fact that each column had to be analyzed separately due to complex geology, the analysis using the FEM Robot Structural Analysis Professional was demanding. This software provides advanced construction simulations and huge capacities for analysis of complex structures. This software is fast, efficient and easily customizable, and calculates complex models. For this structural model, the

arches were modeled as panels, given the appropriate thickness, and stiffness coefficients were used for bearing supports, depending upon the compression modulus below each column. To provide a seismic analysis, the dynamic method was used, so pseudo-static forces were generated for each mode shape. Each of it has its own coefficient of participation in seismic calculation from the total mass of the structure, so quadratic combinations were applied.

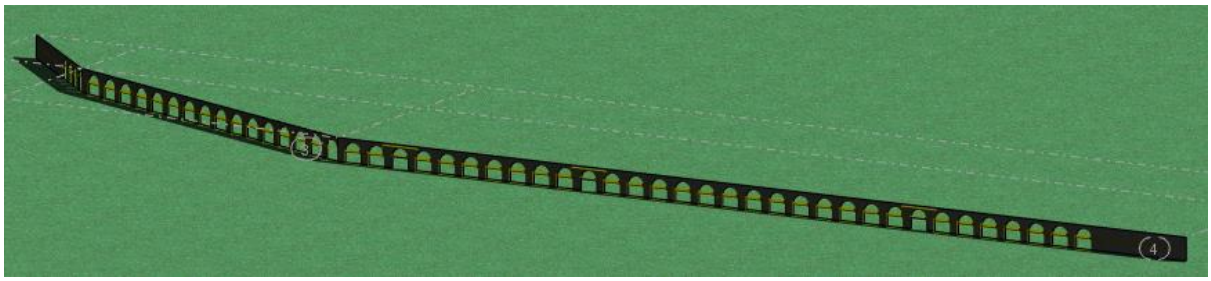

Figure 5 Longitudinal model of the Aqueduct in ROBOT

The results obtained were 2.1 cm maximum vertical deformation from the load case self-weight and when seismic was included, a maximum deformation (buckling) of 0.4 cm was reached (so called, CQC-double sum method).

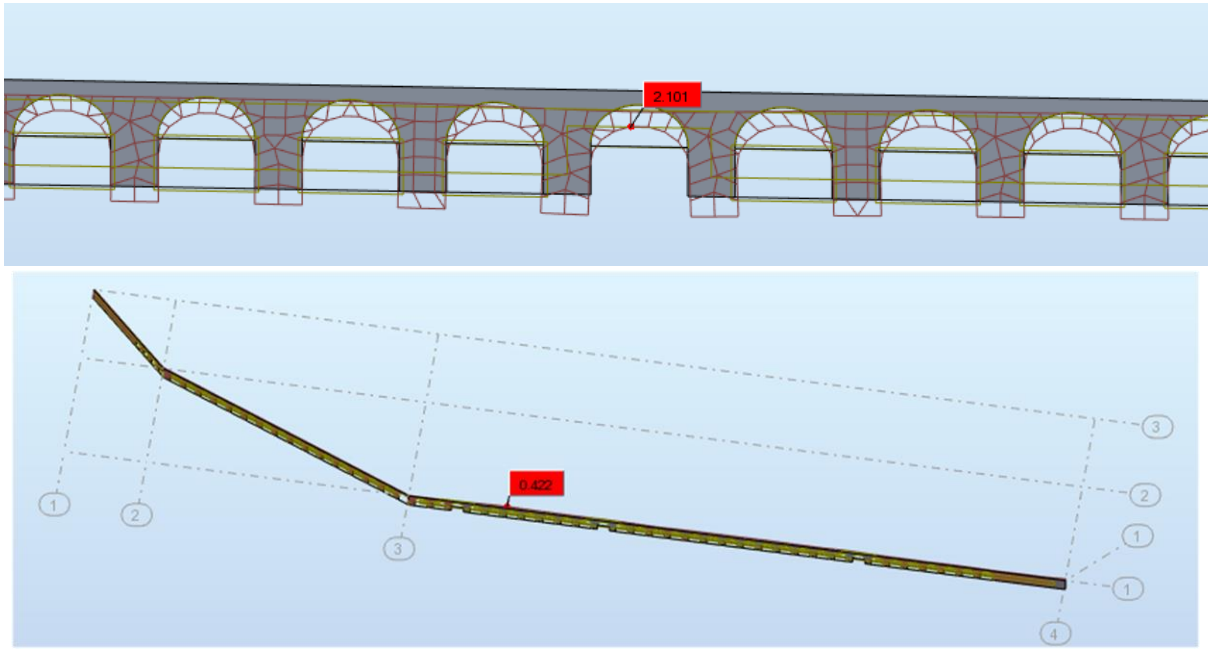

Figure 6 Findings from the modelling in ROBOT: vertical and horizontal deformations

This type of results, in some way, once again confirm the complexity of the problem and the mystery the past has left. This kind of software does not allow heterogeneous layers to be precisely modeled, but instead only stiffness coefficients are used below each column. Another important thing that is left behind is the swell capacity of soil, which proves that probably the seismic is not the main reason for the damage.

2.2. Numerical modelling in PLAXIS 2D

These lacks were overcome with the geotechnical FEM software PLAXIS 2D, which is used to analyze the deformations, stresses, and stability, while considering the non-linear and time-dependent behavior of soil, consolidation of soil, as well as ground water. For such purpose, several soil models were implemented: linear elastic (Hooke's law describes the elastic properties of materials since the force and displacement are proportional), Mohr-Coulomb (linear failure envelope, and increments of in-depth compression modules are included), Hardening Soil Model (where the values of the modulus of

elasticity of soil are entered from different experiments, as static penetration or oedometer test), Soft Soil Creep Model (uses coefficients to describe the strength of the material: κ, λ, μ) and User-defined model (by setting individual values), while for the construction plate-elements were used. So, the compression modulus values below these columns were taken from oedometer test results, and calibrated considering other tests, such as static cone penetration test, while the material of the aqueduct was considered as linear-elastic. Seismic was included as acceleration, considering previous earthquakes at the location.

After such modelling, the results PLAXIS 2D gave is a horizontal displacement of 34.9 cm on top for the most endangered column C13, which describes the complexity of the problem, considering many different factors that affected the building. As for the second group of columns (inclined towards east), the finding was more precise since the results confirmed the real state of column C26 with a horizontal top displacement value of 22 cm.

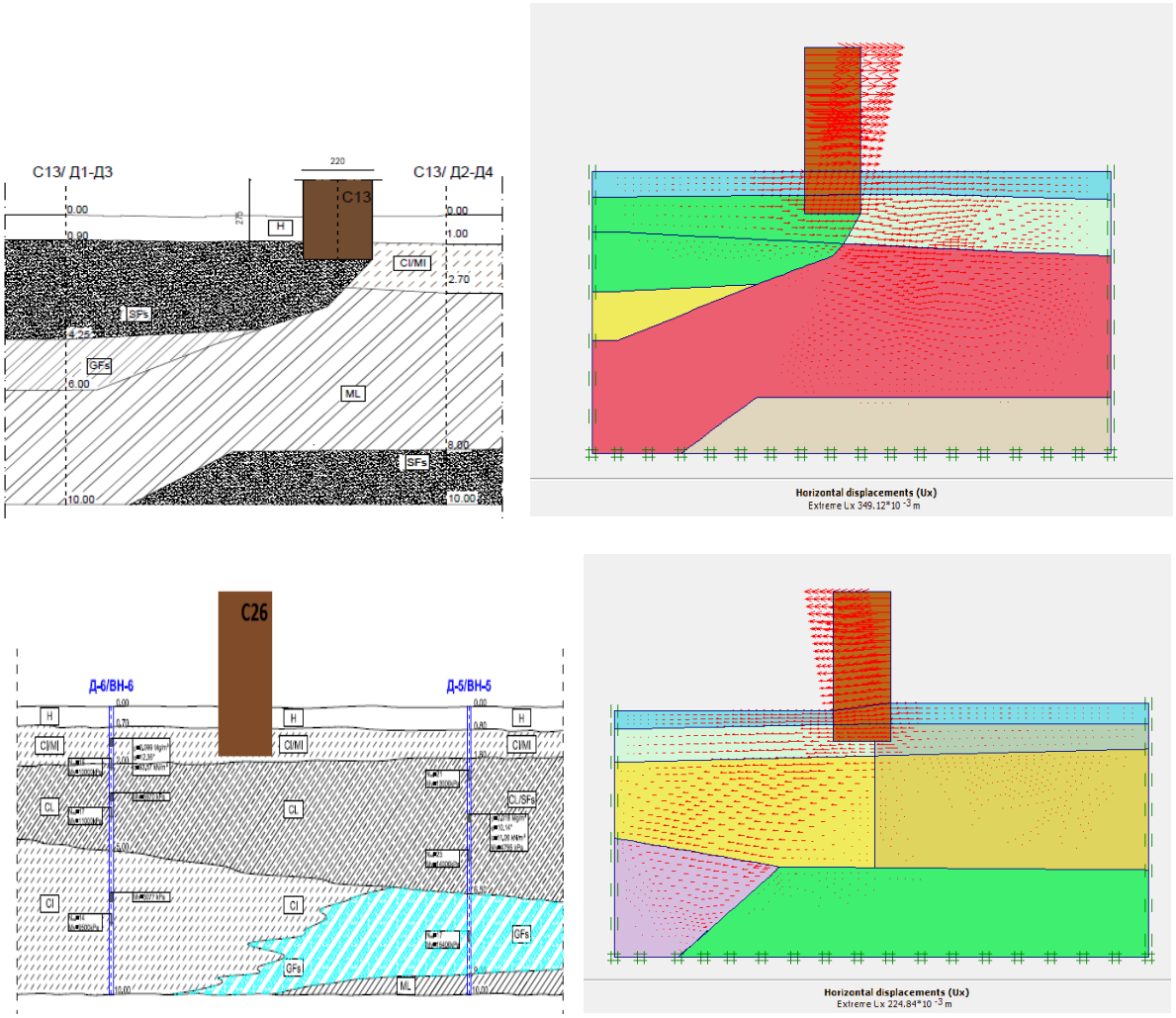

Figure 7 *Complex geotechnical conditions below the columns (C13 – above, left; C26 – below, left) and obtained displacements (C13 – above, right; C26 – below, right)*

To provide a solid solution for this problem, few options were further analyzed in PLAXIS 2D. First, there was an unsuccessful attempt to enlarge the shallow foundation, so two variants of piles were used: large size reinforced concrete piles, and steel self-drilling micro-piles. For each of them two length variants were used: 6 and 8 meters. The results were reducing the 53 cm top horizontal displacement for C13 to only 6 cm and the 22 cm top horizontal displacement for C26 to 4 cm. Given that this is a restoration of a structure that probably dates back to the 15th century, that there are only few data available on the history of deformations and their causes, and that C13 is the pillar with the largest inclination, the results obtained with these piles are considered satisfactory. Confirmation is given also

that 6 cm is 1% of the height of the building, i.e. H/100, which classifies them in the category of acceptable ones.

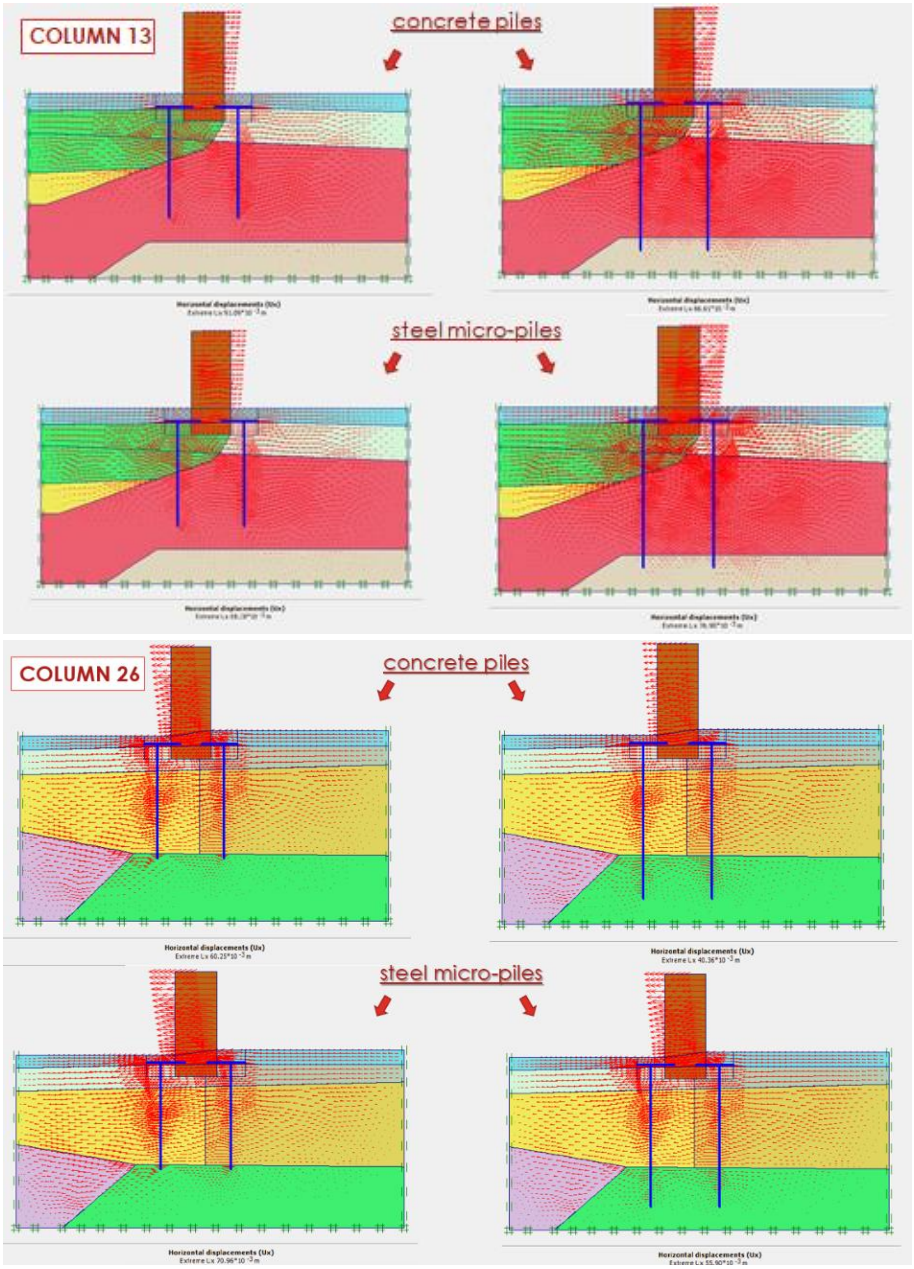

Figure 8 *Calculated displacements after modelling the stabilization measures with concrete piles and steel micro-piles for the aqueduct (C13 – above; C26 – below)*

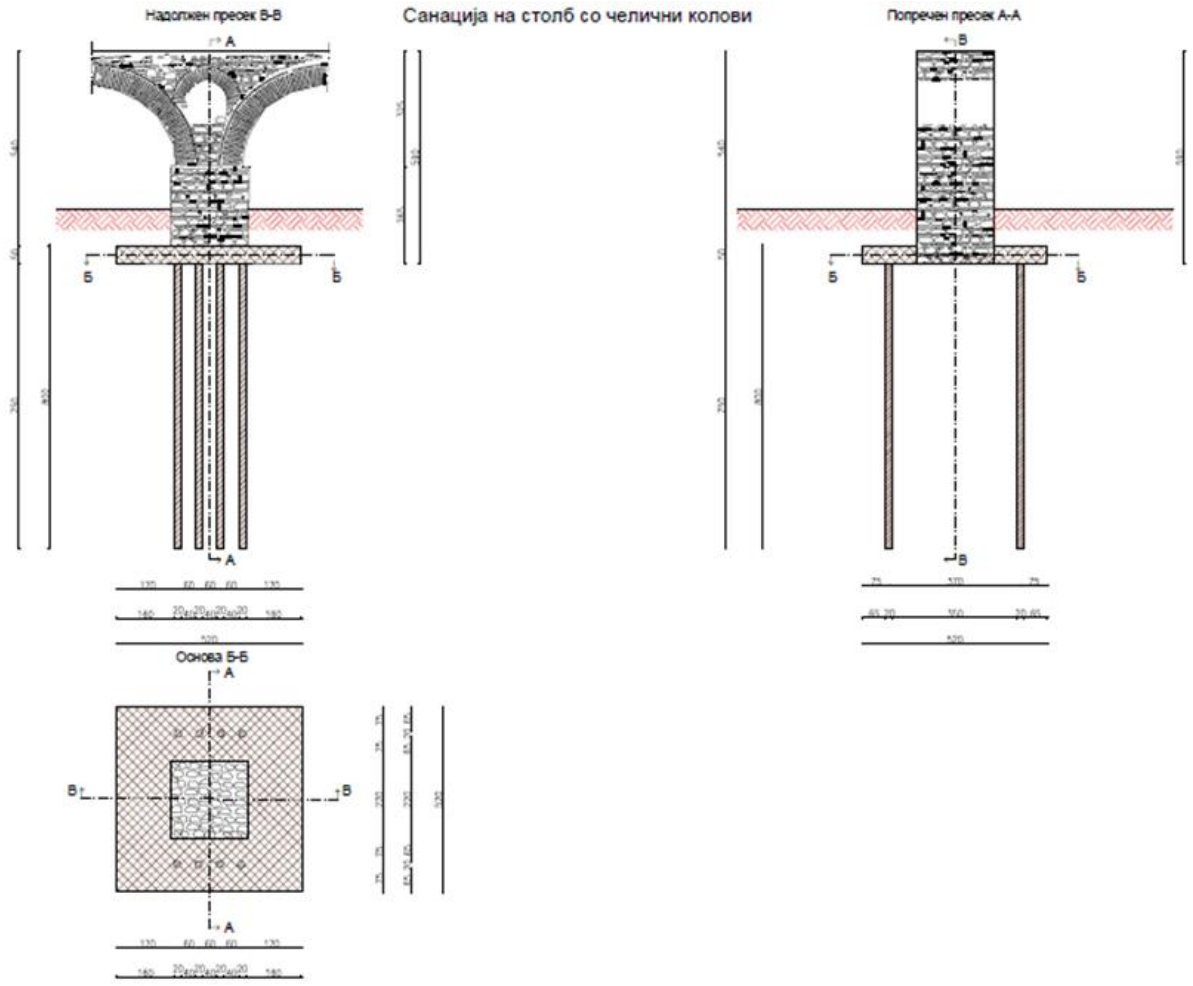

Figure 9 *Possible disposition of stabilization with steel self-drilling micro-piles*

3. Recommendations

Since the costs between the two applied solutions were comparable, the decision which measure is more acceptable had to be delivered from the execution point of view. From that side, the steel self-drilling micro-piles have various advantages:

- dramatically increased production rates
- lower number of positions which ask application of machines nearby the damaged aqueduct
- the procedure causes minimal noise and low vibration
- drilling and grouting procedures do not cause damage to the existing structures
- easy drilling, regardless of soil type
- there is no excavated material
- special drilling and grouting methods allow the load from the micro-circles to be transferred to the ground (enabled at the soil-pile contact through massive friction)

During their execution, it is necessary to protect the aqueduct with scaffolding etc. However, the list of activities for its full repair is not closed here. Namely, there are also other elements that have to be done for the upper structure, as:

- Restore the damaged or demolished parts of the building. For this purpose it is advisable to use materials with physical-mechanical characteristics similar to the existing ones
- Hydraulic lime with additives can be used as a binder
- Cracks should be injected with an injection mixture based on hydraulic binders

4. Conclusion

The paper presented the numerical modelling of the variant solutions for stabilization of the Skopje Aqueduct. Although the focus is on the stabilization measures, for which steel self-drilling micro-piles were adopted, it has to be stressed that it was rather more difficult to calibrate the model with the registered deformations on the structure due to the very complex geotechnical conditions and limited available data on the history of damages. These analyses served as a base for further design and finalization of the project, which is to be completed and realized during 2021.

Namely, on April 20th 2021, at the proposal of the Office for Protection of Cultural Heritage and the opinion of the National Council for Cultural Heritage, the Government of the Republic of North Macedonia declared The Skopje Aqueduct as a cultural heritage of special importance, subcategory of exceptional importance and the restoration project has started. This grandiose and ostentatious building is considered to be one of the most important archeological sites in North Macedonia, historical and cultural heritage of the country, so it commanded respect: the stabilization measures described above contribute this.

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Modifications Techniques for Wood/Thermoplastic Filaments Used in 3D Printers

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Abstract:

A 3D prototype manufacturing has become quite widespread nowadays. Particularly, there is increasing interest to desktop 3D printers because they allows the user to easily produce objects directly as 3-Dimensional CAD (Computer Aided Design) images. The main reasons in the increase of 3D printers are unlimited product customization, less waste than traditional subtractive methods, and easy to use. As a function of increasing 3D printer, the demand for the filaments have also increased in last decade. The filament used in the 3D printers can be produced different materials. Although the neat fossil based thermoplastics was still the most used filaments, environmentally friendly filaments are preferred by the user because of harmful effects of fossil based thermoplastics to the environment. The filament producers has focused on the production of natural fiber/thermoplastic filaments as an alternative to petroleum based thermoplastic filaments. The major drawback of natural fibers is incompatibility with biodegradable or non-biodegradable polymers, which adversely influence the physical and mechanical properties of filaments, as well as printed objects. This study gives the modification techniques for wood/PLA filaments used 3D printers.

Keywords: *Natural fibers; Wood; Thermoplastic; Filament; 3D printer; Modification; Additive manufacturing*

1. Introduction

3D printing is known as additive manufacturing (AM) process, where the final product is produced layer by layer. It enables to users to create a product directly from a virtual computer model (Fig. 1). It is one of the latest manufacturing technologies and has been widely used by the users due to its simple usage. 3D printers opens numerous new possibilities for the production of complex shaped products.

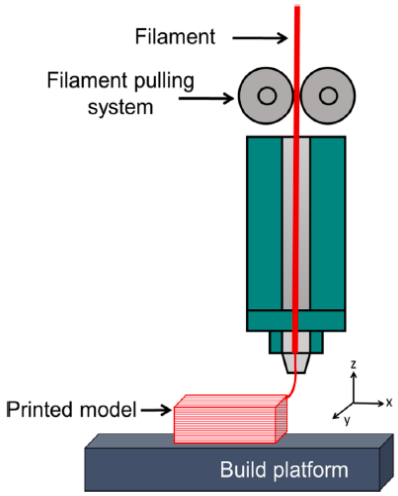


Figure 1 *Details of the 3D printing technology (Shanmugam et al. 2021)*

Today, man-made fibres have been noteworthy replaced with plant fibres in composite industry such as in automotive, housing, packing, medical, and other high value-added applications due to their significant advantages such as low-cost, short growth period, renewability and wider availability, non-toxic, good mechanical properties, environmentally friendly properties, and modest abrasivity during processing despite two drawbakcs, substantial hydrophilicity and poor compatibility (Ayrilmis et al., 2021). Increasing society consciousness and government environmental legislations and policies force the polymer composite manufacturers to use plant fibres in their products instead of synthetic fillers/fibers. When the wood flour is added into the thermoplastics, the cost of material for 3D printers will obviously decrease. The users prefer nature-friendly filaments in the 3D printers. Raw materials, production of filaments and 3D printing of the filaments are presented in Figure 2.

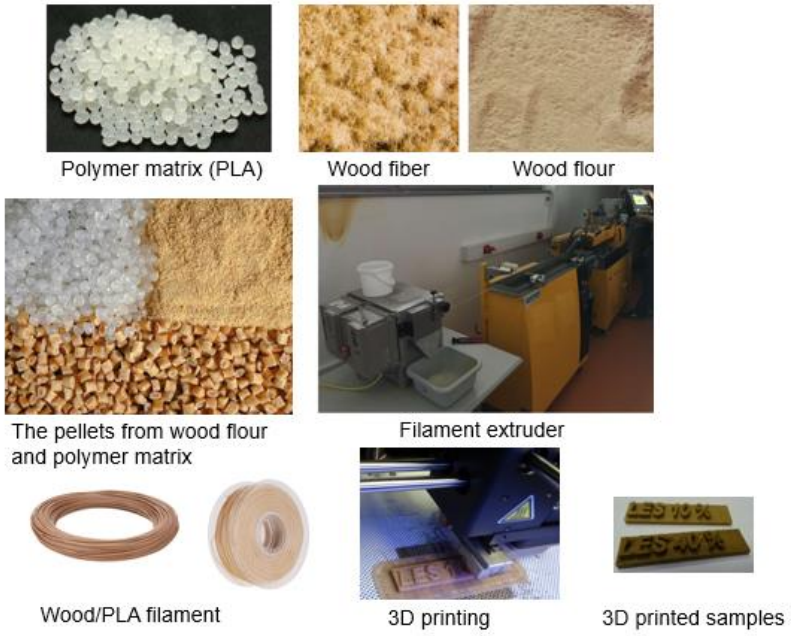


Figure 2 *Raw materials, production of filaments and 3D printing of the filaments*

The advantages of natural fibers are given below (Bledzki and Gassan, 1999; Mohanty et al., 2005; Ayrilmis et al. 2021):

- Biodegrable and sustainble material
- It can be processed easily like wood.
- It has higher hardness than properly unfilled plastic.
- High dimensional stability
- Low specificity compared to mineral fillers,
- Price advantage when combined with expensive plastics,
- Short processing time
- Good thermal and sound insulation
- Possibility of recycling
- Its price is cheaper than synthetic fibers
- High electrical resistance
- Being machinable and reducing machines during production compared to inorganic fillers
- Superior mechanical properties relative to their density

The disadvantages of natural fibers are as follows (Bledzki and Gassan, 1999; Mohanty et al., 2005; Ayrilmis et al. 2021):

- Inferior mechanical properties and dimensional stability properties as compared to the synthetic fibers
- lnferior compatibility between natural fiber and polymer surface
- Changing natural fiber quality depending on the geographic conditions
- Thermal degradation above 200 °C in the extruder
- Low biological durability

Functions of polymer matrices:

- Binds natural fibres(Provides a medium for binding and holding the natural fibres together in a solid)
- Contribute to the transfer and distributing externally applied loads to the fibres (Matrices helps for transfer working stress to the fibres)
- Protect fibres against to moisture, water, weathering and biological attacks (The fibres are embedded into the matrices. Matrices envelop the fibres and protect them)
- Prevent propagation of cracks
- Separates the fibres (the failure of individual fibres remains localized).
- Provides finish, color, texture, durability.

Functions of reinforcing materials (particles, fibres, continuous or discontinuous filaments):

- Principal load bearing member

The characteristics of wood fibres natural fibres significantly affects the quality of final product Wood/PLA filament manufacturers should consider the characteristics of wood fibres affecting 3D printed product performance as given below (Ayrilmis et al., 2021):

- Wood should not be decayed by fungal attacks.
- Moisture content of wood before mixing with polymer in the extruder or injection molding should be 1% and below.
- The extractive content in natural fibre should be low.
- Density between 0.35 g/cm3 and 0.65 g/cm3 is suitable.
- Coniferous tree species are preferred because of the faster travel in the extruder and faster composite profile drawing.

- The bark should be removed from the wood. Wood without bark should be used in the composite.
- The particle size of the wood should be appropriate according to production process such as such as injection molding, extrusion or hot press molding. Furthermore, particle size affects significantly the mechanical and physical properties of composite as well its moisture content.

2. Modification techniques for wood

The surface of wood fibers has hydrophilic character while the surface of polymer matrix has hydrophobic character. Thus, there is incompatibility between the wood and polymer interfacial area, which decrease the physical and mechanical properties of the wood. A good interfacial bond contribute to the load transfer from polymer matrix to reinforcing filler as the external load is applied. The surface modification techniques applied to the natural fibers given in Table 1 will improve the compatibility between fiber and polymer surface, which improve interfacial bond. The modification techniques are mainly divided three categories which are physical modification–corona or cold plasma treatments; chemical modification – compatibilizers such as maleic anhydride grafted polypropylene or polyethlyene (MAPP and MAPE), alkali treatment, acetylation; thermal-treatment modification; epoxide, silanes; and biological modification (Petinakis et al., 2013; Ayrilmis et al., 2021).

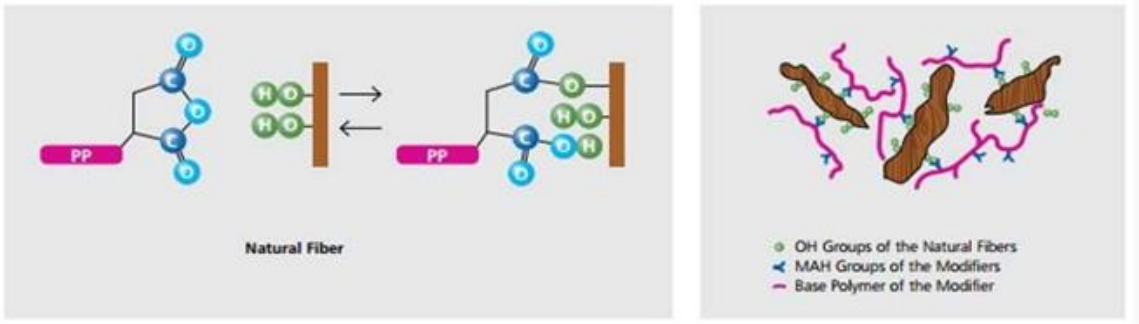
Another problem is that the plant fibres can be thermally degraded above the temperature exceeding 200 °C during the processing. For this reason, natural fibres can be mixed with polymers which melts below 200-220 °C. In addition, the hydroxyl groups in natural fibres can react with water molecules, which cause the linear expansion/contraction and thickness swelling. The natural fibres should be dried below 1% based on the oven-dry weight of wood before processing in the extruder. Otherwise, high moisture content in natural fibres can cause micro voids, gaps, and micro bubbles in the polymer composite (Ayrilmis et al. 2013). These problems can decrease the mechanical properties of the composites. This also causes the dimensional changes and water absorption of the composites, which results in warping in service life. One of the most important problems of natural fibres they are “natural”. Therefore, the natural fibres can be degraded by fungi under suitable conditions such as enough oxygen, temperature, and moisture content. Mold of the fungal type provides increasingly important in the domain of engineering materials and can lead to early deterioration and structural failure. Types of modification for natural fibres to be used in the filament production are summarized in Table 1.

The compatibilizers improve the interfacial bond between wood and polymer by ester bonds. The content of the compatibilizers used in the wood/polymer filaments mainly depends on the filler content (generally 1-4 wt% of MAPP or MAPE). When the filler content is increased in the thermoplastic filament, the addition of the compatibilizers is increased. Compatibilizers forms ester chemical bonds between polar and apolar surfaces (Ayrilmis 2013). Particularly, MAPP or MAPE are the most used modifiers for the wood/PLA filaments Cellulose molecules having hydroxyl group reacts with anhydride binding agent, which form ester bonds (Fig 3).

When the compatibilizer is added into the wood/polymer filament, the interfacial bond improves and the number of pullet out fibers after the tensile test is small. However, when the wood flour content was increased in the composition, the number of the pullet out fibers and the microvoids increase, which shows the lower mechanical properties. In Figure 4, the SEM image of the tensile fracture surface clearly showed that the interfacial bond between walnut shell flour (60 wt%) and polypropylene was strong due to addition of the 3 wt% MAPP. However, at the same filler content, the interfacial bond was weak due to pulled out walnut shell particles uncoupled with MAPP. (Ayrilmis et al., 2013).

Table 1 *Types of modification for natural fibres (Lu et al. 2000, Ayrilmis and Ashori 2005, Pickering et al. 2016)*

Modification type for natural fibers	**Effect of modification**
Alkali treatment	Reduce the lignin and hemicellulose, pectin, and extractive (waxes and fats) content.
Acetylation	Esterification occurs by reaction of acetic groups ($CH_3CO–$) with hydroxyl groups (–OH) on the fibres
Benzoylation	Improve hydrophobicity
Enzyme	Reduce the lignin content
Grafting	Maleic anhydride (MA) grafted polymers (MAPP, MAPE) react with the hydroxyl groups on the natural fibre surface which leads to covalent (ester bonds) or hydrogen bonding. They improve UV-protective properties and fibre-matrix adhesion, hydrophobicity and mechanical properties.
Isocynate	Surface modification
Mercerization	Reduce the moisture regain and improve the mechanical properties
Methacrylate	Improve tensile and flexural strength
Ozone	Affect surface energy and contact angle
Peroxide	Reduce the moisture regain
Plasma	Improve hydrophobicity
Silane	Silanes such as amino, methacryl, glycidoxyand alkyl silanes
Thermal-treatment	Improve fibre-matrix adhesion, hydrophobicity and mechanical properties
Biological-treatment	Improve fibre-matrix adhesion, hydrophobicity and mechanical properties



A. The surface of polypropylene (PP) and natural fibre.

B: Chemical reaction of the modifier with natural fibre (MAH groups).

Figure 3 *The bonding mechanism of the compatibilizer*

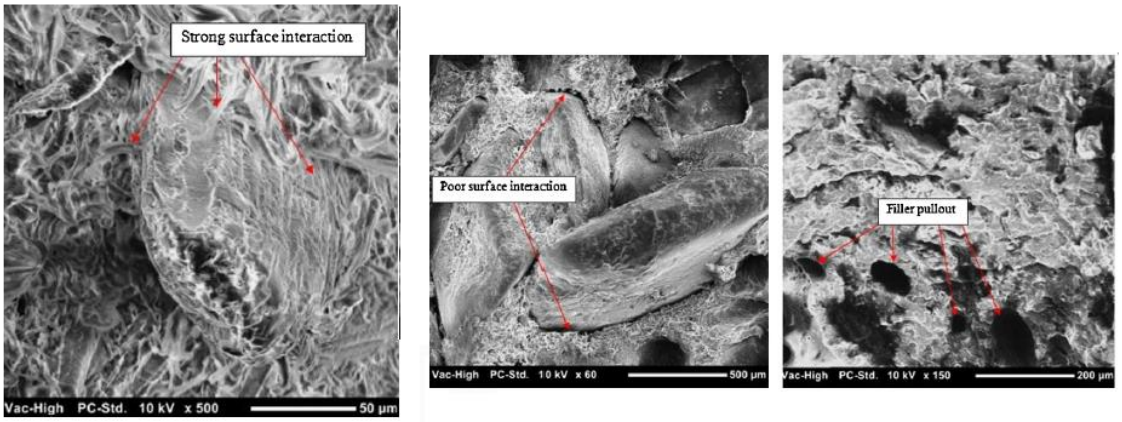


Figure 4 *The SEM images of wood/polypropylene composites. A. wood/polypropylene composite with a compatibilizer (good interfacilal bond) B. poor bond between polyporpylene and wood surface and pulled out fibers on the tensile facture surface*

Filament modified with nanocellulose

Use of nanocellulose as reinforcing filler for the 3D filaments has recently increased due to its excellent properties (Wang et al., 2017; Bardot and Schulz, 2020; Ambone et al., 2020). The nanocellulose has very large surface area at very small weights. In general, 1 g of nanocellulose covers surface are of 100 m2. Thus, the very small addition of the nanocellulose into the filament such as %1-2 wt% is quite enough. The structures of wood cell and nanocellulose are given in Figure 5. Nanocellulose improve the mechanical properties of the thermoplastic filaments, especially modulus.

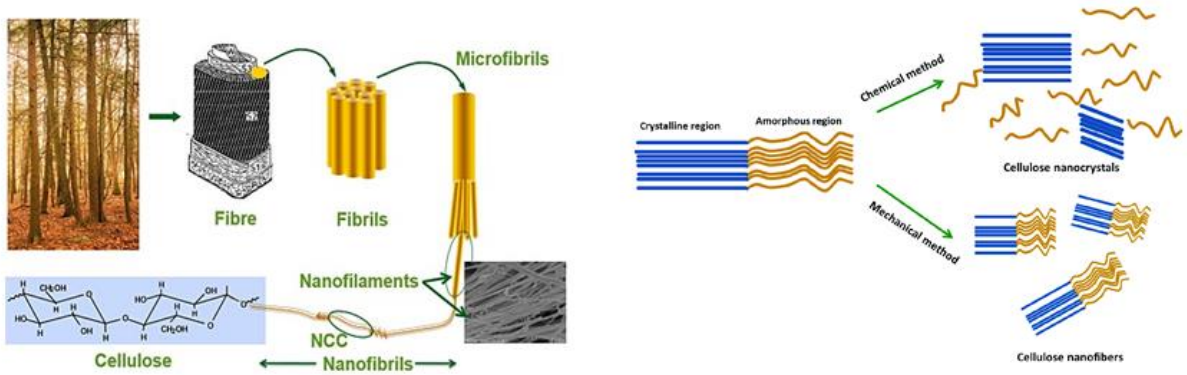


Figure 5 *A: Structure of wood cell; B: Types of nanocellulose (Perumal et al. 2019)*

Advantages and disadvantages of nanocellulose for 3D filaments are as follows (Bledzki and Gassan, 1999; Mohanty et al., 2005; Ayrilmis et al. 2021):

Advantages:

- Low-weight and biodegradable
- Renewable and sustainable
- Excellent mechanical properties and good thermal stability
- High specific surface area
- Modest abrasivity during processing

Disadvantages:

- Hydrophilic character
- Poor compatibility with the polymer matrix

3. Conclusions

Although wood fibers have unique properties as compared to the synthetic fibers, the main drawbacks of wood fibres are their incompatibility with the polymer matrix and hydrophilic property. To minimize these undesirable properties, the surface modification of wood is needed to improve the physical and mechanical properties of the filaments for the 3D printers. Chemical treatment is the most frequently used method among the treatment types. The advantage of this method is primarily the ease with which the process could be controlled compared to physical and biological techniques. The evaluation of modified wood as filler in thermoplastics for the filament production will be one of the most efficient ways to use it in high value-added materials.

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A Review on Utilization of Agro-industrial Residues in Thermoplastic Composites

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Abstract:

Increasing environmental pollution caused by petroleum-based thermoplastics negatively effects marine and other habitats. Furthermore, plastic price has rapidly increased in last decade due to fluctuating petrol price. Thermoplastic composite manufacturers use some fillers to reduce the cost of plastics and improve mechanical and physical properties of the composites. As compared to the synthetic fibers such as glass fibers, lignocellulosic fillers have excellent advantages such as easy-supply, recycling, renewability, low-abrasion to machine tools, biodegradability and easy compostability after disposal. In general, most of the agricultural lignocellulosic materials contains about 10–25% lignin, 20–30% hemicellulose, and 40–50% cellulose. There are a plenty of study on the utilization of agricultural wastes such as sugarcane, wheat straw, sunflower stalk, walnut shell, olive mill sludge, corn waste as an alternative to wood and synthetic fibers in thermoplastic composites. This study reviewed previous studies on the utilization of agro-industrial residues in the bioplastics and petroleum-based plastics.

Keywords: *Agro-industrial residues; Thermoplastic composites; Mechanical properties; Polymer matrix*

1. Introduction

Use of agro-waste materials as a reinforcement in the production of WPCs alleviate the shortage of wood resources, and can have the potential to start a natural fiber industry in countries wherethere are little or no wood resources left. Use of agro-waste materials as a reinforcement in the production of WPCs alleviate the shortage of wood resources, and can havethe potential to start a natural fiber industry in countries where there are little or no wood resources left (Nourbakhsh and Ashori, 2010). Today, man-made fibers have been noteworthy replaced with plant fibers in composite industry such as in automotive, housing, packing, medical, and other high value-added applications industries due to their significant advantages such as low-cost, short growth period, renewability and wider availability, non-toxic, good mechanical properties, environmentally friendly properties, and modest abrasivity during processing despite two drawbacks, substantial hydrophilicity and poor compatibility (Ayrilmis and Ashori, 2015; Ayrilmis et al. 2021). Increasing society consciousness and government environmental legislations and policies force the polymer composite manufacturers to use plant fibers in their products instead of synthetic fillers/fibers. In this chapter, types of natural fibers, chemical and mechanical properties of plant fibers and nanocellulose and their use in polymer composites were studied. The comparison of the specific modulus of the most common natural fibers and E-glass fibers and the cost per weight of some natural fibers and E-glass are presented in Figure 1.

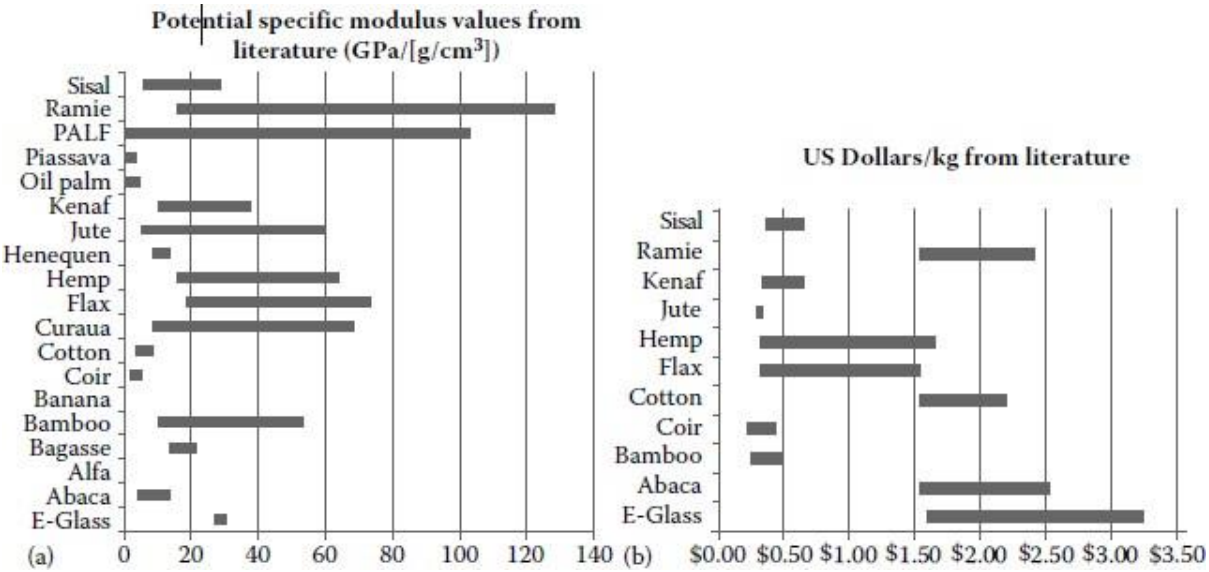

Figure 1 *(a) Comparison of the specific modulus of the most common natural fibers and E-glass fibers. (b) The cost per weight of some natural fibers and E-glass (Campilho, 2015)*

Some examples of natural fiber composites produced from the sugar cane bagasse and polymers such as seat and I-beam are displayed in Figure 2.

Figure 2 *Examples of biocomposites produced using sugarcane particles NaturoMer® (Anonymous, 2021)*

2. Properties of Agricultural Fibers and Their Utilization in Thermoplastic Composites

Structure of cell wall of lignocellulosic plant fiber is presented in Figure 3. As shown, there is a lumen in the center of the lignocellulosic cell. The cell wall consist of primary wall and seconder wall (S1, S2, and S3). The middle lamella is located among the cell walls.

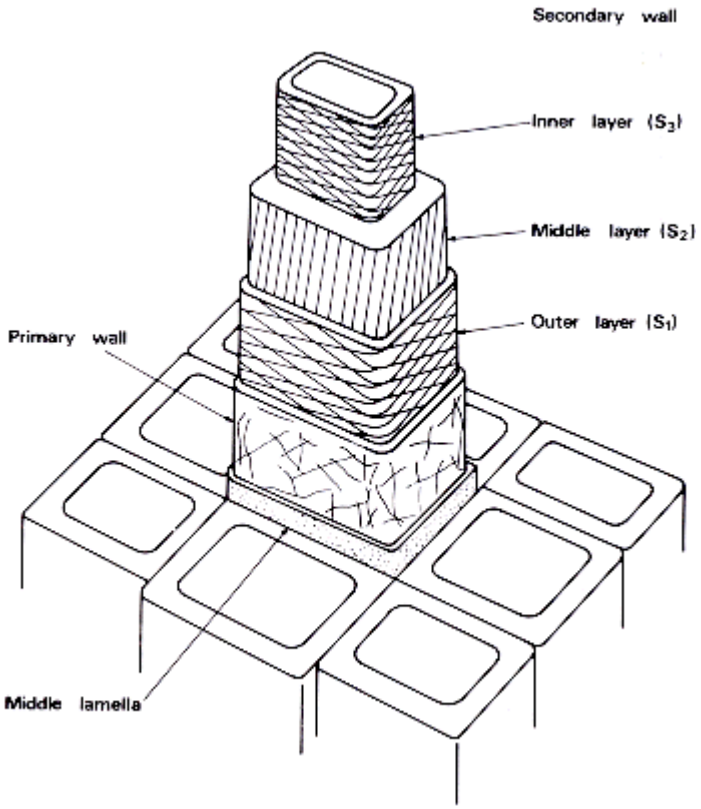

Figure 3 *Structure of lignocellulosic plant fiber (Harris, 2006)*

The amounts of the main components of lignocellulosic fillers differ among plant fibers, even in the same species. The chemical and morphological properties of a natural fiber can be affected by climate,

season, geographic location where the plants are grown up. This is important because the physical and mechanical properties, and thermal/acoustic properties of natural fiber composites are significantly affected by the properties of the fibers. The chemical composition of common agricultural waste is given in Table 1. The highest amount of the cellulose was found in the corn stalks with a value of 61.2%, followed by cotton stalk, sawdust, and others.

Table 1 Chemical composition of common agricultural waste (Sadh et al., 2019)

Agro-Industrial Wastes	Chemical composition (% w/w)					
	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)	Total solids (%)	Moisture (%)
Sugarcane bagasse	30.2	56.7	13.4	1.9	91.66	4.8
Rice straw	39.2	23.5	36.1	12.4	98.62	6.58
Corn stalks	61.2	19.3	6.9	10.8	97.78	6.40
Sawdust	45.1	28.1	24.2	1.2	98.54	1.12
Sugar beet waste	26.3	18.5	2.5	4.8	87.5	12.4
Barley straw	33.8	21.9	13.8	11	-	-
Cotton stalks	58.5	14.4	21.5	9.98		7.45
Oat straw	39.4	27.1	17.5	8	-	-
Soya stalks	34.5	24.8	19.8	10.39	-	11.84
Sunflower stalks	42.1	29.7	13.4	11.17	-	-
Wheat straw	32.9	24.0	8.9	6.7	95.6	7

Knowledge about fiber length and width is important for comparing different kinds of natural and wood fibers. A high aspect ratio (length/width) is very important in cellulose based fiber composites as it give an indication of possible strength properties. In many cases, there is a wide variation in both length and width. All of the natural fibers at the ultramicroscopic level have the same density, which is a cell wall density of approximately 1.5 g/m3. The density of celulose is 1.54 g/cm3 while lignin has a density of 1.46 g/cm3. There is a very wide range of physical properties depending on the fiber type.

The physical and mechanical properties, and the price of the plant fibers and synthetic fibers are given in Table 2. The tensile strength of plant fibers depends on the test length of the specimens, which is of main importance regarding reinforcing efficiency

Table 2 Mechanical properties of natural fibers as compared to conventional polymers and synthetic fibers (Mochane et al. 2019)

Source	**Annual production (million)**	**Origin**	**Price/kg (USD)**	**Density (g/cm^3)**	**Tensile strength (MPa)**	**Young's modulus (GPa)**	**Elongation (%)**	**Moisture content (%)**
Abaca	0.07	Leaf	1–1.5	1.5	430–813	31.1–33.6	2.9–10	14
Bagasse	Abundant	Grass	0.2	0.89	350	22	5.5	
Bamboo	100	Grass	2.2–3.25	0.6–1.25	290	11–17	–	9
Banana	2.5	Leaf	0.1–0.75	1.35	529–914	27–32	2.6–5.9	10–11
Coir	Abundant	Fruit	0.2–0.4	1.15–1.25	131–220	4–6	15–40	10
Cotton	0.0185	Seed	1.5–2.2	1.51	400	12	3–10	33–34
Date palm	4.2		0.025	0.7–1.2		60–80	2–19	
Flax	0.81	Stem	3.11	1.4	800–1500	60–80	1.2–1.6	7
Hardwood	-	Wood	0.44	0.3–0.88	51–121	5.2–15.6		
Hemp	-	Stem	1.55	1.48	550–900	70	1.6–4.0	8

Jute	0.25	Plants	0.926	1.3–1.48	393–800	13–26.5	1.16–1.8	12
Kenaf	0.77	Stem	0.378	–1.4	284–930	21–60	1.6	6.2–20
Nettle	-	Bast	–	1.51	650	38	1.7	11–17
Pineapple	Abundant	Leaf	0.1–018	1.44	413–1627	60–82	14.5	10–13
Ramie	0.1	Stem	2	1.5	500	44	2	12–17
Sisal	0.3	Plants leaf	0.65	1.3–1.4	390–450	12–41	2.3–2.5	11
Softwood	-	Wood	0.44–0.55	0.30–0.59	45.5–111	3.6–14.3	–	–
Wool	-	Animal	-	-	-	-	-	-
Silk	-	-	-	-	-	-	-	-
Feather	-	-	-	-	-	-	-	-
Basalt	-	Mineral	-	2.8	2800	8.5	2.8	-
S-Glass	–	Synthetic	2	2.5	000–3500	70–73	1.8–3.2	–
E-Glass	–	Synthetic	2	2.55	3–3.5	63–67	2.5	–
Aramid	–	Synthetic		1.44	3000	124	2.5	–
Carbon	–	Synthetic	8–14	1.4	400	230–240	1.4–1.8	–
Silicon carbide	-	Synthetic	-	3.16	-	360–440	–	–

The fiber strength can be an important factor in selecting a specific natural fiber for a specific application. Data on the tensile strength of several natural fibers indicates that tensile strength varies widely depending on the type of fiber tested. The changes in physical properties can be due to differences in fiber morphology. Major differences in structure such as density, cell wall thickness, length and diameter do result in differences in physical properties. It is also interesting to note that the morphology of land plant fibers is very different to that of water plant fibers.

Advantages and disadvantages of plant fibers than synthetic in biocomposite production as follows (Bledzki et al. 2002, Sathishkumar et al. 2013, Ayrilmis and Ashori 2015, Peças et al. 2018; Ayrilmis et al. 2021):

1. Environmentally friendly raw material, higher fiber content for equivalent performance, reducing more polluting base polymer content
2. Lower hazard manufacturing process as compared to glass fiber production, the production requires little energy, CO2 is used while oxygen is given back to the environment. Unlike petroleum-derived polymers when burned, they have less environmental impact.
3. Compared to synthetic fibers and polymer matrices, it is relatively inexpensive, thus reducing the cost of the biocomposite and the price of the final product (200 USD per ton while 1 ton of polyethylene is 1200 to 1500 USD).
4. Renewable resource and abundant in nature
5. Good processing and less abrasive damage to processing equipments such as extruder or injection molding machines compared to inorganic fillers, no skin irritation.
6. Outstanding mechanical properties (especially tensile strength and modulus) relative to their density. Low specific weight, which results in a higher specific strength and stiffness than glass fiber.
7. Unlike synthetic fibers during production, the negative impact on humans is much less
8. Good thermal and acoustic insulation (good sound and heat insulation)
9. Recycling and problem-free disposal, low-emission of toxic fumes when fired or exposed to high temperatures
10. Low density, high modulus, high specific strength and stiffness
11. Better energy retrieval
12. High electrical resistance

13. Producible with low investment at low cost, which makes the material an interesting product for low-wage countries.

Disadvantages of plant fibers are as follows (Brouwer 2000, Namwar et al. 2014):

1. Lower strength properties, particularly its lower impact strength than synthetic fibers
2. Poor compability with hydrophobic polymers
3. Varying plant quality geographic conditions such as weather, plant growing, soil properties.
4. Inferior dimensional stability and moisture absorption caused by hydroxyl groups. They negatively affects the mechanical properties and interfacial bonding between the polymer matrix and fiber
5. Limited maximum processing temperature. Higher processing temperature above 200-220 °C causes thermal degradation and limiting polymer matrix options.
6. Lower biological durability, Modification of fibers increases the durability.
7. Low fire resistance
8. The production cost is fluctuated by agricultural politics and harvesting conditions

The moisture of agricultural fillers affects significantly the properties of the thermoplastic composites. Higher moisture contents in the natural fibers results in microbubles, gaps, and voids in the composites during the processing in the extruder (Ayrilmis et al. 2013). In addition, the pellets prepared from fillers of agricultural waste and polymer matrix should be dried before injection molding. The defects caused by moisture cause lower mechanical properties and water absorption in the composites. The lignocellulosic fillers cannot be used directly in its natural form. The surface of the fillers has a hydrophilic structure having hydroxyl (OH) groups, which prevents the compability with the hydrophobic polymer surface and results in lower mechanical properties (Ayrilmis and Ashori 2015). Some surface modification techniques make the lignocellulosic fillers more hydrophobic to improve the interfacial bond between the filler and polymer matrix while some techniques makes chemical bonds between the hydroxyl groups of fibers and surface of polymer using coupling agents. In addition, the surface modification requires to remove the waxy layer of agricultural fillers to improve the interfacial bond.

There are a plenty of study on the utilization of agricultural waste as reinforcing filler in thermoplastic composites (Ayrilmis et al., 2013; Pickering et al., 2016; Mochane et al., 2019; Kuzmin et al., 2021). For example, Kuzmin et al investigated mechanical properties of barley straw/HDPE composites produced with extrusion process. They reported that the addition of the 42 wt% barley straw particles into the HDPE increased the tensile strength from 23.1 to 28.2 MPa. Especially, the tensile modulus of the composites increased sharply (230 to 1700 MPa).

3. Conclusions

This study focused on the properties on the properties of agricultural wastes and their utilization as filler in thermoplastic composites. The thermoplastic materials utilizing residues from agricultural and industrial processes, represent an important environmental alternative to the polymer composites. Due to their renewability and biodegradability, industrial use of agricultural waste in high value added polymer composites may contribute to the decrease in the amount of synthetic fiber which are non-environmental friendly materials after disposal.

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Automotive Interior Applications of Natural Fiber Reinforced Polymer Composites

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Abstract:

Today, man-made fibres have been noteworthy replaced with plant fibres in composite industry such as in automotive, housing, packing, medical, and other high value-added applications industries due to their significant advantages such as low-cost, short growth period, easy supply, recycling, low-abrasion to machine tools renewability and wider availability, non-toxic, good sound absorbing efficiency, good mechanical properties, environmentally friendly properties, and modest abrasivity during processing despite two drawbacks, substantial hydrophilicity and poor compatibility. As compared to glass fibre reinforced polymer composites, the natural fibre composites reduce the weight of the automotive interior components, which lower the required energy for the manufacture by 80%. With the increasing awareness of consumers towards the environment, their interest in sustainable environmentally friendly materials is increasing. Automotive industry have focused on the sustainable and cost-effective light-weight biocomposites because the energy consumption of a vehicle is mainly depended on its weight. Bast fibres such as flax, hemp, jute, and kenaf are widely used in automotive interior applications such as dashboards, door panels, parcel shelves, seat cushions due to their unique properties. This study reviewed recent studies on the automotive interior applications of natural fibre composites.

Keywords: *Natural fiber composites; Automotive, polymer composites; Bast fibers*

1. Introduction

Cellulosic fibres are becoming very interesting for enhancing the mechanical properties of thermoplastics such as polyethylene and polypropylene. Natural fibres possess unique properties such as good mechanical properties, low density, environmental benefits, renewability, sustainability, high acoustic damping, and economic feasibility. These properties make the natural fibres attractive for the automotive industry. Utilization of the natural fibres as reinforcing filler in the automotive industry has considerably increased in last decade. Particularly, flax and hemp fibres are the most preferred natural fibres in automotive interior applications due to their significant advantages than glass fibre. Two main reasons for the utilization of natural fibres in the automotive industry are reduced car weight and fuel economy. The density is glass fibre is 2.5 g/cm3, hereby increases the weight of the automotive. This results in higher oil consumption. Bast fibres have distinctive features such as high tensile strength and modulus, low flexibility, and different lengths. The density is glass fibre is 2.5 g/cm3 which increases the weight of the automotive. This results in higher oil consumption. Natural fibres are classified based on their origin, which are seed fibres, leaf fibres, bast fibres, fruit fibres, and stalk fibres. Nonwood fibres, especially bast fibres, are widely used in the polymer composites of automotive. Among the nonwood fibres, bast fibres have significant properties such as high tensile strength and modulus, low flexibility, and different lengths. They are obtained from the stem of the plants. Commercial bast fibres used in automotive industry are flax, hemp, jute, kenaf, and ramie. Classification of natural fibres is presented in Figure 1.

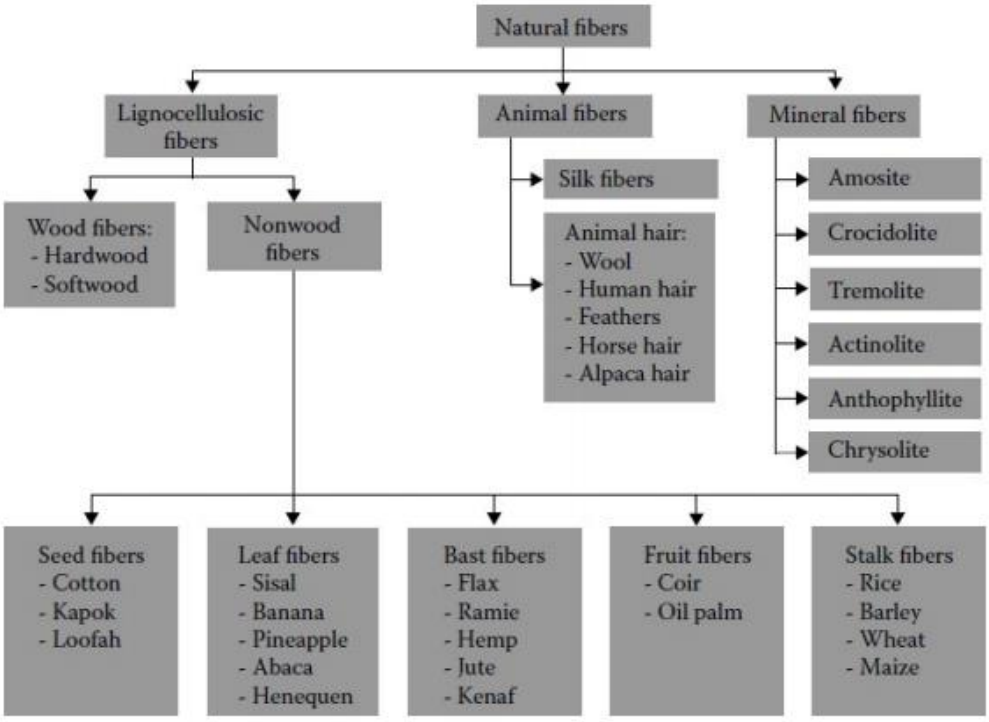

Figure 1 Classification of natural fibres

The energy and cost comparison of natural fibre, glass fibre, and carbon fibre are given in Table 1. The required energy for natural fibres is quite lower than the man-made fibres as well as production cost. Carbon fibre is the most expensive fibre than others and required higher energy.

Mechanical properties of the natural fibres, synthetic fibres, and polymers are given in Table 2. Although the tensile strength of synthetic fibres is higher than natural fibres, the young's modulus of the hemp and ramie is similar to the E-glass and S-glass fibres. The lower density of the natural fibres is a significant feature as compared to the synthetic fibres.

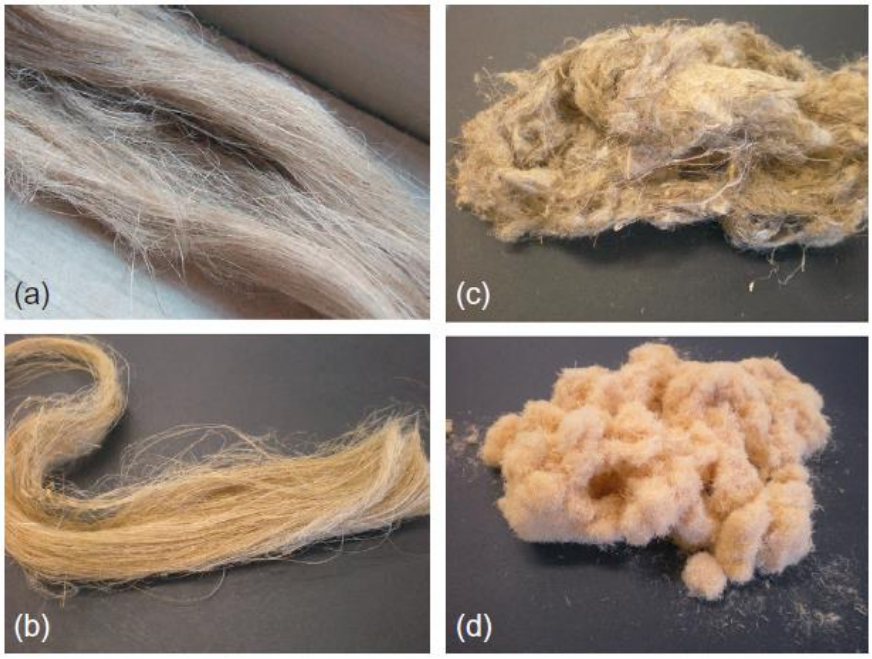

Figure 2 *(a) Flax sliver, (b) hemp sliver, (c) flax hackling tow and (d) thermomechanical pulp (TMP) fibre*

Table 1 *The cost and energy consumption of natural fibres (Pecas et al.)*

Type of fibre	**Cost (US$/ton)**	**Energy (GJ/ton)**
Natural fibre	200–1000	4
Glass fibre	1200-1800	30
Carbon fibre	12,500	130

Table 2 *Mechanical properties of natural fibres as compared to the synthetic fibres and conventional polymers*

Fibre	Density (g/cm^3)	Elongation (%)	Tensile strength (MPa)	Young's modulus (GPa)
		Fibres (Reinforcements)		
Cotton	1.5-1.6	7.0-8.0	287-800	5.5-12.6
Jute	1.3	1.5-1.8	393-773	26.5
Flax	1.5	2.7-3.2	345-1035	27.6
Hemp	1.5	1.6	690	70
Ramie	1.5	1.2-3.8	400-938	61.4-128
Sisal	1.5	2.0-2.5	511-635	9.4-22.0
Coir	1.2	30.0	175	4.0-6.0
Viscose (cord)	-	11.4	593	11
Soft wood (kraft)	1.5	-	1000	40
		Synthetic fibres		
E-glass	2.5	2.5	2000-3500	70.0

S-glass	2.5	2.8	4570	86.0
Aramid (normal)	1.4	3.3-3.7	3000-3150	63.0-67.0
Carbon (standard)	1.4	1.4-1.8	4000	230.0-240.0
		Polymers (Resins/Matrices)		
ABS	1.05	10	55	2.8
Polycarbonate	1.22	100	62	2.3
Polyetherimide	0	-	105	2.8
Nylon	1.12	29	66	3.5
Polyethylene (HDPE)	0.95	30	28	1.04
Polypropylene	0.9	200	35	0.83
Polystyrene	1.05	15	35	2.76
Epoxy Resin	-	6.2	32	0.5

2. Industrial Applications of Natural Fibres in Automotive Applications

Bast fibres, in particular hemp, flax, and kenaf, are commercially used to enclose the rear side of seat backrest and inside of door. Cotton fibres are generally evaluated as sound proofing material. Coir fibres are used as interior trim and seat cushioning. Door trims can be produced from polyurethane reinforced with non-wowen mat of individual or hybrid bast fibers. Improvement in the noise reduction is obtained using natural fiber-based cargo floor tray (Vijayanand et al., 2018).
Typical amounts of natural fibres used in different automotive interior applications are given below (Ashori, 2008):

- Front door linens: 1.2-1.8 kg
- Rear door linens: 0.8-1.5 kg
- Boot linens: 1.5-2.5 kg
- Parcel shelves: up to 2.0 kg
- Seat backs: 1.6-2.0 kg
- Sunroof sliders: up to 0.4 kg
- Headliners: average 2.5 kg

Ford Motor Company, one of the biggest automotive producers has increased the utilization of natural fibres in their cars. For example, they use wheat straw which is agricultural waste as reinforcing filler in the polypropylene for the door application (Fig. 3).
In other application, Ford Motor Company used kenaf fibres in the bolsters (inside parts of doors) of Ford Escape model. It was observed a reduction of 25% in the total weight of the door bolster, which contribute greatly to fuel savings (Fig. 4).
Daimler-Mercedes Benz company also one of the biggest automotive companies using natural fibres for interior applications (Fig. 5). Generally, hot-press molding technology is more commonly used to produce relatively big pars such as back car seat.

Figure 3 *Wheat straw reinforced polypropylene composite for automotive application*

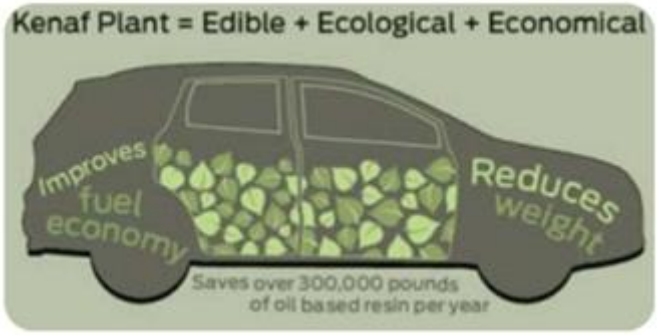

Figure 4 *Advantages of kenar fibre application in the in the bolsters of automotive*

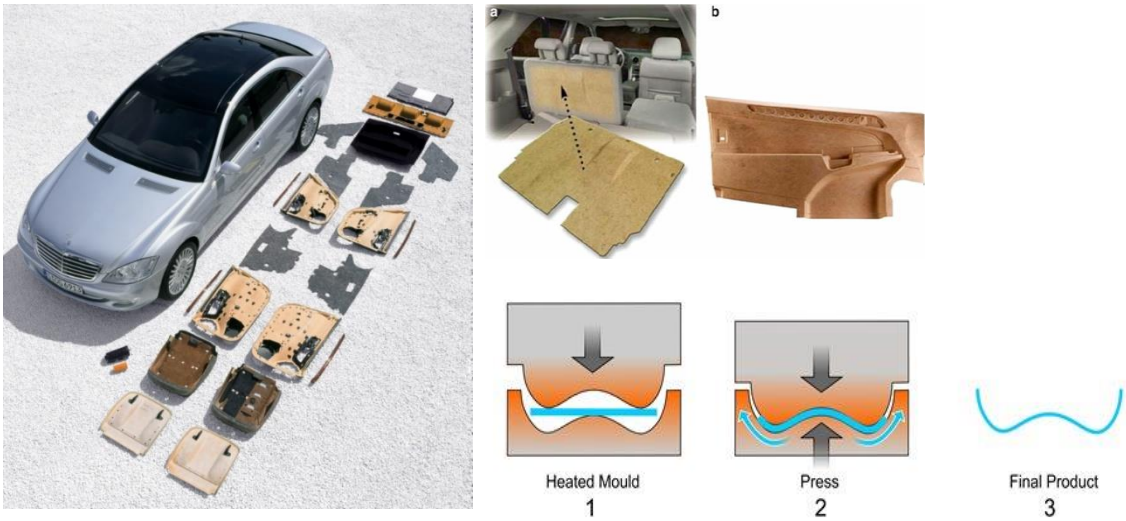

Figure 5 *Application of natural fibres in the automotive interior parts*

Flax fibre is one of the most used the bast fibres in the composite industry due to its unique properties. The high tensile strength and stiffness of flax fibre and low elongation at break are the important features of the flax fibre which make it especially attractive composite research in automotive industry. Consequently, this fibre is anticipated as a reinforcing material in thermoplastic or thermoset based composites in replacement of the widely used E-glass fibres.

Hemp fibres are mainly used in the automotive industries as reinforcement of door panels, passenger rear decks, pillars and boot linings. Hemp fibre is preferred for very cost-effective, high strength as an alternative to glass fibre, with quite lower price. Figure 6 shows the production of automotive door from non-woven hemp mat. Some interior door applications of the natural fiber polymer composites Figures 6-8.

Figure 6 *Production of automotive door*

Figure 7 *Hemp fibre reinforced polymer composite*

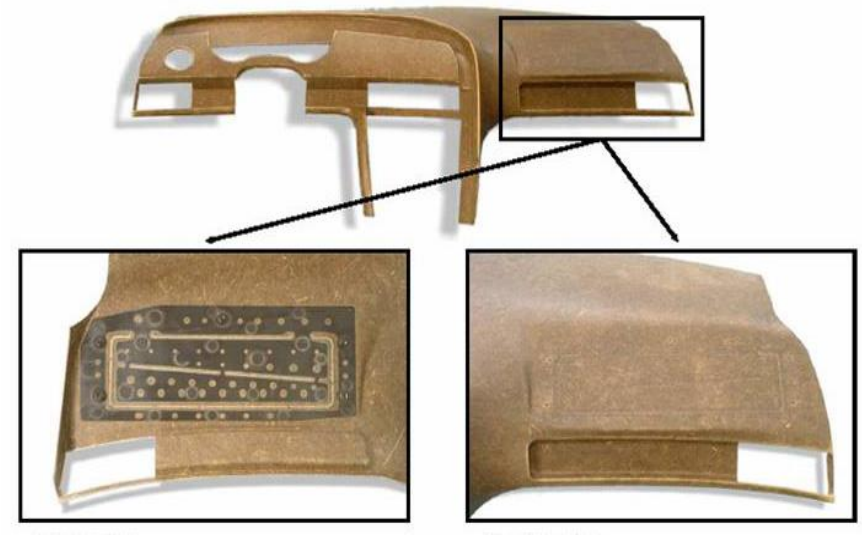

Figure 8 *Automotive interior door panel integrated with airbag flap produced from natural fiber reinforced polymer composites (Bledzki et al., 2006)*

The natural fiber composites is also used under floor protection trim of the automotive (Fig. 9).

Figure 9 *Under floor protection trim of Mercedes A class made from banana fibre reinforced composites (Denault, 2015)*

Natural fibers such as flax, kenaf, and hemp fibres have been recently replaced with glass fibers indoor applications of the vehicles due to their low-cost, low-density, acceptable specific strength properties, their great strength/weight and stiffness/weight ratios, more shatter resistant, and sound insulation capability, enhanced energy recovery, and biodegradability. Automotive industry is developing sustainable low-weight biocomposites with noise reduction capability for fuel efficiency.

3. Conclusions

Automotive industry have focused on the safe and cost-effective light-weight vehicles because the energy consumption of a vehicle is mainly depended on its weight. Natural fiber composites offer important opportunities in this context. Furthermore, with the increasing awareness of consumers towards the environment, their interest in sustainable environmentally friendly materials is increasing. The findings of academic and industrial research revealed that interior components of the vehicles can be efficiently produced from light-weight natural fiber composites with acceptable strength properties.

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Mechanical Properties of 3D Printed Natural Fiber Reinforced Polymer Composites: A Short Review

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Abstract:

In recent decades, a strong development in the field of polymer composites reinforced with natural fibers (wood, flax, jute, etc.) has been observed. In fact, these materials is more commonly known under the term of biocomposites, eco-composites or green composites. They are often prepared by incorporating fibers into polymers matrix using different manufacturing methods such as 3D printing. Indeed, 3D printing and natural fiber-reinforced polymer composites will provide specific mechanical properties. However, the determination of these properties is essential in order to explore the potentiality of their applications in different fields. This paper gives an overview on 3D printing techniques of polymer composite materials and their potential applications in several fields. Common 3D printing techniques such as fused deposition modeling, selective laser sintering and stereolithography are introduced. The mechanical testing and performance analysis of 3D printed natural fiber-reinforced polymer composites, in particular, fused deposition modeling (FDM) is presented to evaluate the mechanical properties. Finally, significant restrictions are highlighted to motivate the future research of 3D printing.

Keywords: *3D printing; Biocomposites; Fiber polymer composite; FDM; Mechanical properties*

1. Introduction

Additive manufacturing, commonly called "3D printing", appeared in the last quarter of the 20th century, with the stereolithography (SLA) of C.Hull [1]. Since then, many techniques have been developed; each has its advantages and disadvantages. The most popular today are fused deposition modeling (FDM or FFF), stereo-lithography (SLA) and selective laser sintering (SLS). Unlike subtractive manufacturing, the additive methods build parts by adding material layer by layer from the virtual CAD model. The process repeats until the entire model is created. Regarding the materials used, polymers are the main raw material. Initially, limited mainly to Acrylonitrile Butadiene Styrene (ABS) and Poly-Lactic Acid (PLA), the range of polymers used in 3D printing is considerable. They are available in a variety of color options. In addition, advances in composite materials allow additive manufacturing to be used for the production of functional parts [2].

3D printed natural fiber-reinforced polymer composites are a relatively new group of eco-materials. After decades of high-tech development of synthetic fibers such as carbon, aramid and glass, it is remarkable that nowadays natural fibers have attracted a great deal of attention due to their important properties, low production cost, biodegradability, and thermal and sound insulation properties. Today, several sectors are interested to these materials, like automotive [3] where the manufacturers are using natural fiber composites in a wide range of their products, such as door panels, seat backs, headliners package trays, dashboards, and interior parts. They can also be used in sports equipment, biomedical field [4] and construction [5].

Despite the various advantages of 3D printed natural fiber-reinforced composites, the major obstacle to their use is the lack of knowledge of their mechanical properties. Indeed, the evaluation of these properties and the study of the parameters which can influence them, makes it possible to obtain parts with better mechanical properties. For that, good control of the technique is necessary, which passes by the use of optimal parameters. The present paper is a short review of the mechanical test of natural-fiber reinforced composites fabricated through AM, in particular fused deposition modeling (FDM). The review underlines the effect of various processing parameters, involved in the FDM of polymer-fiber composites on the mechanical behaviors.

2. Material and Method

Natural fiber-reinforced polymer composites are manufactured through many techniques such as extrusion molding, compression molding, injection molding and rotational molding. But the parts produced by the latter are often inferior in mechanical properties, so fused deposition modeling (FDM) can be a credible alternative to solve this problem.

FDM process is based on the extrusion of molten filament being deposited, cooled, and solidified in a layer-by-layer manner to form a three-dimensional part [6]. The part is first created using computer-aided design software, and then the resulting 3D model is cut into several layers by a "slicer" before being sent to the printer. Numerous printing parameters must then be set, ranging from the temperature of the extruder and the platform on which the successive layers are deposited, to the specifics of the print path. Among the latter, let us quote the distance between two neighboring filaments on the same layer or their orientation angle. Other parameters on which we can play are fiber weight percentages, fiber geometry, fiber size, fiber length, etc. All these parameters obviously have an impact on the printing time and the quality of the manufactured part.

Polymers, more commonly called plastics, can be divided into two large families: thermosets and thermoplastics. Their main difference is their transformation in front of the temperature: the thermosets are solidified by irreversible chemical reactions, while the thermoplastics have a melting point but also a glass transition temperature. Above its glass transition temperature, Tg, and below its melting point, Tm, they become solid again and this in a reversible way. Therefore, they have the advantage of being able to be shaped more than once and are considered recyclable.

FDM technology is compatible with this category of materials, although it can print filaments reinforced with natural fiber. Indeed, natural fibers have been used for 3000 years in composites; they are obtained from various natural sources such as plants, animals and minerals. Plant fibers are the most widely used fibers; they are classified according to their source and physiological properties. The fibers obtained from the stems are called bast fibers (flax, hemp, kenaf, jute, isora, etc.). There are also leaf fibers (sisal, abaca, curaua, palm, etc.), seed fibers (cotton, soybean, kapok, calotropis procera, etc.), fruit fibers (coir, loofah, etc.), grass fibers (bamboo, wheat straw, baggase, etc.) and wood fibers such as hardwood and softwood (teak, rosewood, birch, etc.). The choice of one fiber over another can be motivated by the mechanical, physical and chemical properties of the fibers. Today, the market for 3D printing filaments can be considered mature, and the trend is to improve their mechanical properties.

3. Mechanical Properties of 3D Printed Natural Fiber Composite

In order to improve the mechanical properties of the parts manufactured by FDM, two ways are used. The first is to improve the properties of the raw material by adding different types of reinforcements to the filaments. The second, which has become almost indispensable, is to find the optimal parameters for printing.

To date, very limited literature related to the development and characterization of 3D printed polymer-natural fiber composites have been available. Kariz et al. [7] examined the effect of wood content in FDM filament on properties of 3D printed parts. They showed that tensile strength increased up to 10% wt wood content and decreased if the proportion of wood is further increased. Martikka et al. [8] measured the mechanical properties (tensile and impact) of 3D printed wood particulate PLA composite. The tensile and impact strengths of 3D printed parts were found lower than the pristine PLA polymer. The tensile strength and impact strength of developed composites were found approximately 58% and 53% lower than the PLA. Tao et al. [9] conducted a study on wood flour-filled PLA composite. They reported that after adding wood fiber, the initial deformation resistance of the composite was improved but as the fiber content increases, the mechanical properties become lower than the PLA. Ahlawat et al. [10] discussed the effect of graphene nanocomposite on the mechanical properties of the FDM Polymer nanocomposite. They demonstrated that by adding nanoparticles the Young's modulus increased while the ultimate strength decreased Figure 1.

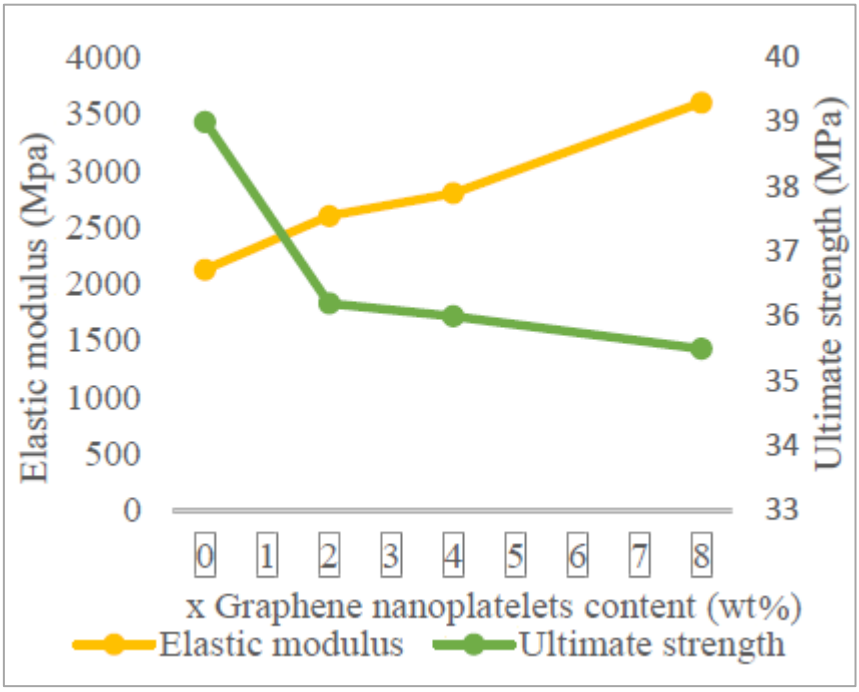

Figure 1 *Elastic modulus and ultimate strength values for pure ABS and ABS(wt. %) graphene-based nanocomposite [10]*

Another example of natural fiber reinforcement involves hemp fibers mixed into polypropylene (PP) matrix was studied by Milosevic et al. [11]. The composite exhibited 50% and 143% improvement in the tensile strength and modulus, respectively when compared to the pure PP. Matsuzaki et al. [12] examined the mechanical properties of 3D printed jute yarn-PLA composite using a simultaneous impregnation process. It was noted that the specimens provided a longitudinal stiffness of 5.11±0.41 GPa, strength of 57.1±5.3 MPa and strain at failure of 1.81±0.44%. In other study, Tekinalp et al. [13] compared the tensile strength of ABS/carbon fiber composites prepared by FDM process and compression-molded. They concluded that the tensile strength improvement for FDM samples was close to that for compressive molded samples. The difference between the achieved results was due to the presence of gaps between deposition lines and poor bonding between polymer and fiber in FDM parts.

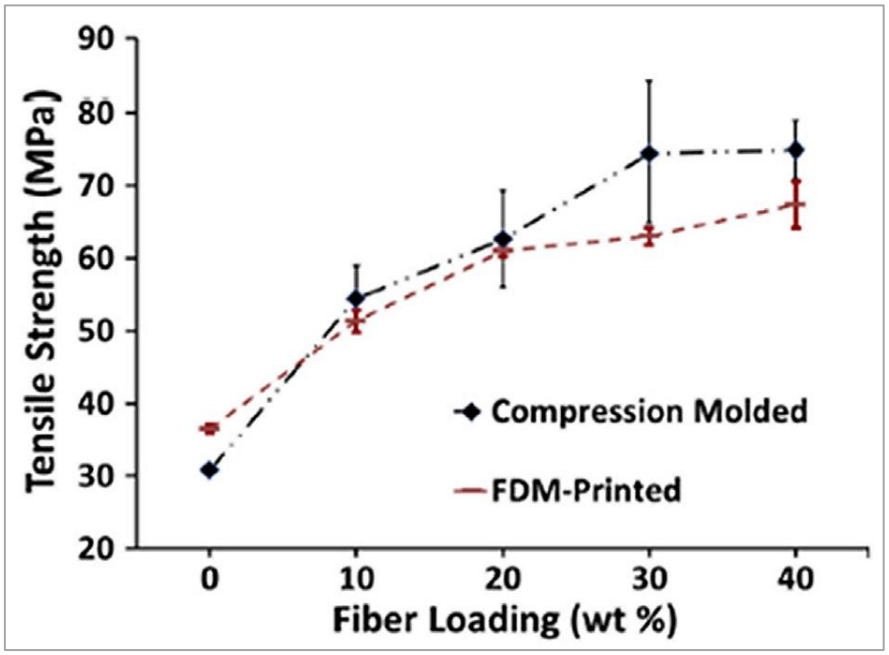

Figure 2 *Effect of fiber content and preparation process on tensile strength of the printed ABS/carbon fiber composite [13]*

As mentioned earlier, the printing parameters significantly influence the mechanical properties of the parts. These parameters were considered in several studies to promote the development of FDM technology. Le Duigou et al. [14] investigated the effect of FDM parameters on the microstructure of 3D printed PLA-wood composite and its consequences on hygro-mechanical properties. They noticed that the printing width (100, 200 and 300%) influenced the mechanical properties of specimens by modifying their microstructure (porosity). The effects of build orientations and raster angles on the mechanical responses of samples created by FDM with different additives, i.e. wood, ceramic, aluminum, copper and carbon fiber-based PLA composites was performed and compared by Liu et al. [15]. They concluded that wood and carbon fiber reinforced PLA had better printing formability than the ceramic, copper and aluminum-based PLA in the upright orientation. In addition, adding wood and chopped carbon fiber into the virgin PLA significantly decreased its mechanical properties. Moreover, PLA composite samples printed in on-edge orientation with +45°/−45° raster angles had the highest mechanical strength in most cases. While all the samples printed along upright orientation had the weakest mechanical strength and modulus due to weak interlayer bonding. In another study, Kain et al. [16] investigated the effect of the infill orientation and the fiber content (15 and 25 wt%) on the compressive strength of the wood fiber-reinforced PLA composite. The infill orientation had a direct effect on the compression strength of the PLA composite. The increase in the fiber content increased the compression strength of the composite. The maximum compression strength of 70 N/mm2 was noted for 25 wt% of wood fiber composite printed with 15 ° infill orientation. Ayrilmis et al. [17]

performed a research on the effect of printing layer thickness on technological properties of 3D-printed specimens fabricated from wood flour/PLA filaments having a diameter of 1.75 mm. The results showed that the tensile and bending properties of the specimens significantly improved with decreasing printing layer thickness.

4. Conclusion

Applications of 3D printing techniques are always increasing as it reduces the gap between idea conceptualization and product development. In addition to virgin polymers, 3D printed natural fiber-reinforced composites have been developed by researchers and their properties are studied for applicability in a specific field. Although, extensive research has been performed to develop such materials which have no impact on the environment. Researches on the characterization of 3D printed natural fiber-reinforced composites are still limited which motivates the researchers for further studies in this area. The present review focused on the introduction of the FDM technique and the literature available on the mechanical properties of 3D printed natural fiber-reinforced composites.

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