ISSN 2303-4521

Periodicals of
Engineering and Natural Sciences

VOL. 5 NO. 2
(2017)

Published by International University of Sarajevo

Periodicals of Engineering and Natural Sciences (PEN)

Periodicals of Engineering and Natural Sciences (ISSN: 2303-4521) is an international open access single-blind review journal published online.

Publication frequency: Semiyearly (1. January - June; 2. July - December).

Publication Fees: No fee required (no article submission charges or processing charges).

Digital Object Identifier DOI: 10.21533/pen

Editorial Office

Mailing Address

Hrasnicka cesta 15
71000 Sarajevo
Bosnia

Principal Contact

Benjamin Durakovic
Managing Editor
International University of Sarajevo
Hrasnicka cesta 15
71000 Sarajevo
Bosnia
Phone: +387 33 957 229
Email: pen@ius.edu.ba

Available online at:

http://pen.ius.edu.ba

Editorial Team

DOI: 10.21533/pen

Publication Frequency

Expected frequency of publication is twice per year:
1. January - June;
2. July - December.

Journal items can be published collectively, as part of an issue with its own Table of Contents. Alternatively, individual items can be published as soon as they are ready, by adding them to the "current" volume's Table of Contents.

Open Access Policy

This journal provides immediate open access to its content on the principle that making research freely available to the public supports a greater global exchange of knowledge.

Journal Ethics and Malpractice Statement

PEN Journal is committed to ensure and uphold standards of ethical behavior at all stages of the publication process, whereby such values also rely on editors, reviewers, contributors and authors who are expected to behave ethically. The standards are based on Committee on Publication Ethics' (COPE) code of conduct, and provide guidelines for best practices in order to meet these requirements. The following ethical guidelines are only intended to give a summary of our key expectations of editors, peer-reviewers, and authors but if you have any questions or concerns please also feel free to contact the Editor of the Journal.

1. Ethical Expectations

Editors' responsibilities

- To carry out their duties in a fair, objective and consistent manner, without discrimination on grounds of gender, sexual orientation, religious or political beliefs, ethnic or geographical origin of the authors.
- To take care that each article undergoes the proper peer-review process.
- To promote consistent ethical policies of PEN journal, and to ensure the confidentiality of the reviewing process.
- To uphold integrity in their work as editors of the journal, doing away with any personal interest, so that articles are considered and accepted solely on their academic merit and without commercial influence.
- To work with authors, reviewers, and the Editorial Board members to ensure the implementation of journals' ethics and publishing policies.
- To adopt and follow reasonable procedures in the event of complaints of an ethical or conflict nature, in accordance with the policies and procedures. To handle process of complaints and giving authors an opportunity to respond any complaints. All complaints should be investigated and the documentation associated with any such complaints should be retained.

Reviewers' responsibilities

- To act objectively, fairly and in a timely manner in reviewing submitted manuscript with the aim of improving its quality such as pointing out relevant published work, which is not cited, etc.
- To alert PEN in case of any competing interest that could affect the impartiality of their reviewing, or any potential conflict of interest that includes any relationship between reviewer and author, or any content that is substantially similar to that under review.
- To conduct themselves fairly and impartially.
- To keep the confidentiality of the review process and to not retain or copy the manuscript.

Authors' responsibilities

- To ensure that their work submitted to the journal is original and authored by them and has not been previously published nor under consideration or accepted for publication elsewhere.

DOI: 10.21533/pen

- To ensure that original ideas, data, findings and materials taken from other sources (including their own published writing) are properly documented and cited. Any content reproduced from other sources author should have permission.
- To ensure that their data is their won, true and not manipulated. Thus, authors are responsible to maintain accurate records and to provide access to their data associated with their manuscript.
- To ensure their work does not violate any rights of others, including privacy rights and intellectual property rights. In addition, authors should ensure that any studies involving human or animal subject are in accordance with local lows and requirements.
- To declare any real or apparent conflicting or competing interest at any stage during the publication process that could be considered or viewed as exerting an undue influence on his/her duties.
- To alert PEN in case if a significant error in their publication is identified and correct any errors prior or subsequent to publication of their work.
- To adhere to all research ethics guidelines of their discipline, and to ensure that authorship and/or co-authorship of the paper was accurately represented.

PEN responsibilities

- The journal and the publisher shall ensure that good practice is maintained to the standards outlined above.
- To deal with research misconduct allegations appropriately when it is occurred. The journal and the publisher shall undertake reasonable actions to identify and prevent the publication of papers where research misconduct has occurred.
- To maintain the editorial independence of journal editors.
- To support journal editors in ethical and academic matters.
- To ensure critical and objective assessment of all articles by reviewers and referees. To keep an accurate and transparent record, including publishing corrections and retractions when necessary.
- The following commonly recognized procedure for dealing with unethical behavior is adopted.

2. Procedures for Dealing With Unethical Behavior

Identification of unethical behavior

- Misconduct and unethical behavior may be identified and brought to the attention of the editor and publisher at any time, by anyone.
- Misconduct and unethical behavior may include, but need not be limited to, examples as outlined above.
- For an investigation sufficient information and evidence should be provided. All allegations should be taken seriously and treated in the same way, until a successful decision or conclusion is reached.

Investigation

- An initial decision should be taken by the editor, who should consult with or seek advice from the publisher, if appropriate.
- Evidence should be gathered, while avoiding spreading any allegations beyond those who need to know.

Minor breaches

- Minor misconduct might be dealt with without the need to consult more widely. In any event, the author should be given the opportunity to respond to any allegations.

Serious breaches

- Serious misconduct might require that the employers of the accused be notified. The editor, in consultation with the publisher should make the decision whether or not to involve the employers, either by examining the available evidence themselves or by further consultation with a limited number of experts.

Outcomes (in increasing order of severity; may be applied separately or in conjunction)

DOI: 10.21533/pen

- Informing or educating the author or reviewer where there appears to be a misunderstanding or misapplication of acceptable standards.
- A more strongly worded letter to the author or reviewer covering the misconduct and as a warning to future behavior.
- Publication of a formal notice detailing the misconduct.
- Publication of an editorial detailing the misconduct.
- A formal letter to the head of the author's or reviewer's department or funding agency.
- Formal retraction or withdrawal of a publication from the journal, in conjunction with informing the head of the author or reviewer's department, Abstracting & Indexing services and the readership of the publication.
- Imposition of a formal embargo on contributions from an individual for a defined period.
- Reporting the case and outcome to a professional organization or higher authority for further investigation and action.

Originality and Plagiarism Policy

Authors by submitting their manuscript to PEN declare that their work is original and authored by them, their work submitted to PEN has not been previously published, original ideas, data, findings and materials taken from other sources (including their own published writing) are properly documented and cited, their work does not violate any rights of others, including privacy rights and intellectual property rights, their data is their won, true and not manipulated. Plagiarism in whole or in part without proper citation is not tolerated by the Journal. Manuscripts submitted to the journal will be checked for originality using anti-plagiarism software.

DOI: 10.21533/pen

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June2017, pp. 103~116
Available online at:http://pen.ius.edu.ba

Assessment of Solar Energy Source Distribution and Potential in Zambia

Mabvuto MWANZA[1], Jamel CHACHAK[1], Numan S.ÇETIN[1],Koray ÜLGEN[1]
[1]Solar Energy Institute, Ege University

Article Info

Article history:

Received Jan 03rd, 2017
Revised Apr04th, 2017
Accepted June 16th, 2017

Keyword:

Solar energy potential
Zambia
Solar Radiation
Renewable energy technology
Photovoltaic

ABSTRACT

Zambia is vastly endowed with a wide range of energy resources. Yet, to date, Zambia has not fully exploited its potential in solar energy utilisation for electricity generation due to various reasons such as lack of understanding of the distribution of solar energy potential in the country and limitation of access to solar energy resource information. This paper assesses the solar energy distribution and potential in Zambia. Nine provinces with different geographical and climatic regions that makes up Zambia were assesed. The distribution of solar radiation within the country were assessed using spatial analysis in ArcGIS Software. The 22year period solar datasets were considered for assessment. These datasets were obtained from NASA Atmospheric Science Data Center using Surface Meteorology and Solar Energy. The analyzed results indicate that Zambia has approximately 20,442TWh/year technical solar energy potential and receives 2109.97kWh/m2 of solar energy per year with 4403.12hours of sunshine. The country has 186,121km2 available and suitable land area for RETs implementations. This study is important as it present an overview of the technical solar energy potential for Zambia which is vital for decision making, energy mix and sustainable deployment of solar energy technologies in the country.

Corresponding Author:

Mabvuto MWANZA,
Solar Energy Institute,
Ege University,
35100 Bornova, Izmir, Turkey.
Email: mabvuto_mwanza@yahoo.com

1. Introduction

Energy is one of the basic necessities for the survival of human race. It is also important for the progress of the nation and essential factor for economic development. In other words, the absence of access to energy has a negative impact on human race and any country's economic development. The use of solar energy technologies nowadays is increasing in the world and most of the countries are trying to follow the move [1]. This has resulted in studies in order to assess the energy potentials and also show the need to use renewable energies in order to protect our planet and the environment around us [1, 2]. Sustainable deployment and implementations of any energy projects and diversification of energy for generation mix within any country, the first step involves identifying and assessing the energy source potentials of that country [1,3,4]. However, in most developing countries like Zambia the availability of solar energy resource information is limited due to lack of wide distribution of meteological stations for collecting weather data across the country[1]. This has resulted in little research and challenges in thorough assessment of solar energy potential in the country. As such, satellite solar datasets are the best alternative to use for assessing solar energy potential for most developing countries[3,4,5]. Satellite datasets have been used in many researchs and have showed that there was good correlation with the local measured datasets[4,6].

The paper aims at studying and assessing the solar energy source distribution and potential in Zambia. For this purpose, the paper focuses on assessing the solar energy potential for nine provincess that makes up Zambia. As the country is targeting to reach sustainable development goals with the target of increasing access to energy for rural and urban areas in Zambia [7], therefore, this study is a must and very important for decision making, generation mix, and deployment of various solar energy technologies in the country.
The rest of the paper is structured as follows. In section II, a brief description of study area is given, followed by the description of energy sector in Zambia in section III. The section IV focuses on stating the renewable resources in Zambia. While section V focuses on the methodology and data collection and section VI deals with the models used. The section VII mainly focuses on the analysis of the results and finally the conclusion of the paper is summarized in section VIII.

2. The Study Area

2.1. Geographic Description

Zambia is located in the heart of Southern Africa at the latitude of 8 to 18 degrees south of the equator and longitude 22 to 34 degree east of prime meridian with an area of 752,614 square kilometers [8]. Over 98.77% of Zambia's surface is taken up by land leaving only 1.23% covered by surface water such as rivers, streams, lakes and other inland water. It has no access to the sea or ocean. The country is surrounded by eight neighboring countries namely; Tanzania and Democratic Republic of Congo (DR Congo) to the North, Angola to the West and Namibia to the South West; Botswana and Zimbabwe to the South; and Mozambique and Malawi to the east as shown in fig. 1 below [8,9]. It is divided into nine provinces with 72 districts, namely; Lusaka, Southern, Eastern, Western, North Western, Copperbelt, Central, Luapula and Northern provinces as shown in fig. 2. It has a population of approximately 14,638,510 people (2014 estimates) of which 58% lives in rural area and 42% lives in urban areas [8,10,11]. According to [8, 12], only about 3% of the rural population are electrified leaving the majority of the population to depend on wood fuel and other traditional energy sources for their household energy needs. This lack of access to electricity and modern services undermines the pace and scope of economic development in the nation. Furthermore, it is also one of the major obstacles for poor people in Zambia to move away from poverty and take development into their own hands and upgrade their quality of life. This has also caused unimaginable deforestation and desertification of the woodland to almost irreversible levels in some parts of the country [13].

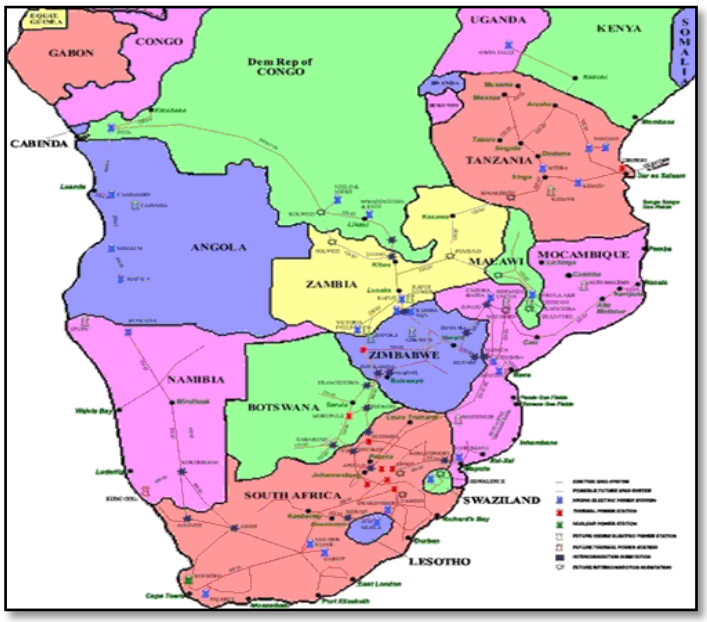


Figure1. Zambia Location and Neighboring Countries and International Grid [7,14]

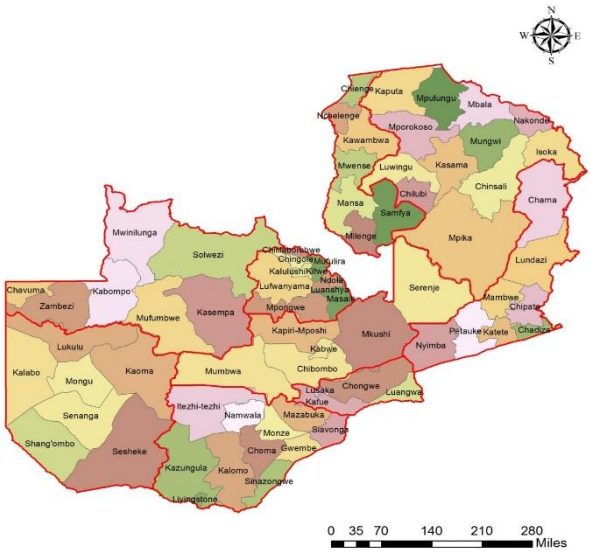


Figure2. The Provinces and Districts in Zambia

2.2. Electricity Industry in Zambia

The electricity supply industry in Zambia mainly comprises of a vertically integrated state utility, Zesco, and an energy service company Copperbelt Energy Corporation (CEC) that purchases power from Zesco and supplies it to the mines [15,16]. In addition, two Independent Power Producer, Lunsemfwa Hydro Power Company (LHCP) and Zengamina Power Company (ZPC) and some small-scale solar based energy service companies supplying power to some rural areas also participate in the industry. Zesco currently dominates electricity generation, transmission, distribution and supply in Zambia [13].

2.2.1. Electricity Supply

The electricity supply in Zambia originated in 1960 when a small thermal station was built in Livingstone to serve a section of the town. Since then the supply system has grown, as of 2013, the country have installed capacity estimated at 2000MW [15]. However, the generation available out of the installed capacity is 1895MW of which about 90% comes from hydro source. Of the total installed capacity about 93% and most of off-grid installed capacity are owned by Zesco. LHCP and CEC are the biggest private operators in the country owning a capacity of 52.5MW and 80MW respectively. While ZPC is one of the smallest private operator owning a capacity of 750kW off-grid system and supplying electricity to 745 customers in North-Western Province. Table 1 summaries the main players in electricity sector in Zambia [13].

Table 1. Main Players in Electricity Sector [17]

Power Station	Capacity (MW)	Type of Technology	Operator
Kafue Gorge	990	Hydro	Zesco
Kariba North Bank	1080	Hydro	
Victoria falls	108	Hydro	
Lusiwasi	12	Hydro	
Off-Grid	49	Hydro/Diesel	
Lusemfwa	28	Hydro	LHPC
Mulungushi	24	Hydro	
Gas Turbine	80	Gas	CEC
Off-grid	0.75	Hydro	ZPC
Off-Grid	0.06	Solar PV	REA

2.2.2. Energy Demand

The electricity consumption in Zambia has been rising steadily estimated at approximately 6% per year (150-200MW). The peak demand varies depending on the season; the winter peak demand was about 1450MW

while the summer peak demand was about 1400MW as in 2009. However, in 2014 the peak demand was forecasted to be between 2,260MW and 2,612MW [16,18]. The energy demand is expected to reach 16.6TWh by fiscal year 2020 and 21.6TWh in fiscal year 2030 respectively [19,20].
As in many other Sub-Saharan African Countries, traditional wood fuel such as charcoal and firewood has remained the major energy source in Zambia contributing about 70% to the total energy demand [8,13]. While, hydropower contributes about 14% to the total energy use and it is the second most used source. Petroleum products accounts for about 12% of the national energy demand. However, coal contributes a small share of about 2% to the total energy supply, despite its good potential in the southern province. Other energy sources such as renewable energy only contribute about 2% to the total energy balance in Zambia. Figure 1 summarizes the contribution of different types of energy sources [13].

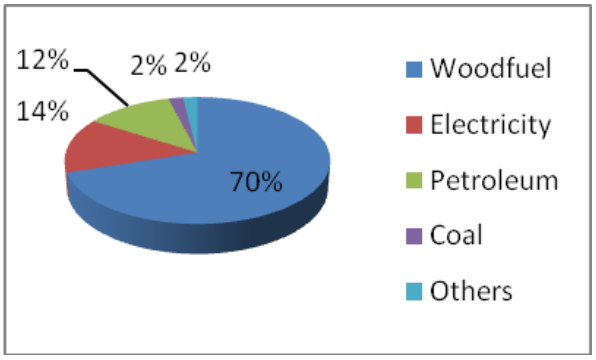


Figure3. Total Primary Energy Supply [13, 17]

2.3. Renewable Energy Resources

2.3.1. Hydropower

The existing estimates of hydro potential in Zambia stands at about 6,000 MW excluding small, mini and micro hydro potential, which is estimated at 45MW [21]. Only about 30% of the estimated Zambia's hydro potential has been harnessed. The Government of Zambia through Rural Electrification Authority has identified 29 locations of mini hydro schemes in the North-Western and Northern Luapula provinces of Zambia. Nonetheless, in order to increase harnessing power from hydro, the government of Zambia is /has continued studying the development of several projects as listed in table 1 below [15].

Table 2. Hydro Potential Sites in Zambia [13,15,16, 19]

River	Description	Capacity (MW)
Kafue	Kafue Gorge Lower	750
	Itezhi Tezhi	120
Kalungwishi	Kalungwishi Hydro	247
Luangwa	Lusiwasi Extension	40
Kabompo	Kabompo Gorge	40
Luapula	Mambilima Falls	698
	Mombututa Gorge	490
	Lunangwe falls	96
Zambezi	Batoka Gorge	1600
	Devil's Gorge	1000
	Mpata Gorge	543
	Chavuma Falls	10-20
	Ngonye Falls	80
Lufubu	Lufubu	80
	Mulembo/Lelya	280
Mita Hills Reservoir	Muchinga	230
Mpika	Mutinondo/Luchenene	70

2.3.2. Biomass

Conversion of Biomass to electrical power potential stands at 500 MW of which 447 MW could be from Agro wastes, 46 MW from forest wastes and 4MW from municipal wastes [19]. Currently Zesco in

conjunction with Global Environment Facility (GEF) /United Nations Industrial Development Organization (UNIDO) plans to install a 1 MW biomass power plant in Kaputa District in order to replace the current 440kW diesel power plant [7, 19, 22]. Furthermore, according to feasibility done by SNV and Hivos in 2012 shows that sixteen (16) of the country's 72 districts have biogas potential (livestock manure) for electricity generation [21,23].

2.3.3. Geothermal

Estimates further indicate that Zambia has potential of generating electricity from geothermal sources; the country has 80 hot springs, of which 35 have potential for power production. Currently, the Government of Zambia is considering constructing a 2 MW of geothermal power plant in Kapisya, Western Shore of Lake Tanganyika. At present, there is only one small-scale 240 kW pilot project that was developed with the support of Italy in 1987[7, 19].

2.3.4. Solar

According to the previous studies and data undertaken by Meteorological Department of Zambia, the country has a significant potential of solar energy for both power production and thermal from solar energy technologies. The country is situated at the latitude of 8 to 18 degrees south of the equator and longitude 22 to 34 degrees east of prime meridian with an average sunshine of about 6-8hours per day and high monthly average solar radiation incident rate of 5.5kWh/m^2/day throughout the year [7, 13,19,24].

To show its comment in increasing access to energy, the Government of Zambia through Rural Electrification Authority (REA) has embanked in PV projects such as installation of a 60 kW solar Off-min grid in Mpanta, Samfya district of Luapula Province, which is supplying about 50 households [24]. Furthermore, REA has installed about 250 solar PV systems in schools and buildings of traditional authorities as well as 400 solar home systems under the Energy Service Companies (ESCO) pilot project [7, 13, 24].

However, a thoroughly assessment of the solar energy potential in terms of distribution and extractable potential for energy generation throughout the country has not been done. For this reason, this study is important to undertake a thorough assessment of solar energy potential in Zambia in order to help the decision makers and accelerate RETs deployment in the country [7].

2.3.5. Wind

The country has an ideal plateau landscape which offers some locations where there is potential for wind energy exploitation. This wind energy as a potential area for power generation has not been exploited due to among other reasons the few studies on wind and lack of wind atlas. However, despite the absence of a comprehensive wind atlas for the country, meteorological data recorded over the past three decades indicates that the country has generally untapped wind energy. Estimates measured at height of 10meters indicates that most parts of the country have the wind speed average of 3m/s, the Western Province and Kasama in Northern Province are nonetheless areas with high wind speed with averages of 6m/s suitable for power production [7,19,25].

3. Materials and Method

There are four main types of solar energy potential assessment, namely: resource potential, technical potential, economic potential and market potential as shown in fig.4[26]. However, currently the assessment of solar energy potential in many countries including Zambia often results only in theoretical resource potential (resource potential) which only indicate the amount of radiation at the country's surface [1, 13, 27]. However, for decision making and sustainable deployment of solar energy technologies, it is extremely important to know how much of the available resource potential is extractable for use i.e. technically in terms of capacity and generation. In addition, it is also vital to know how much of the country's surface area is available and suitable for solar energy technology implementation [1, 27].

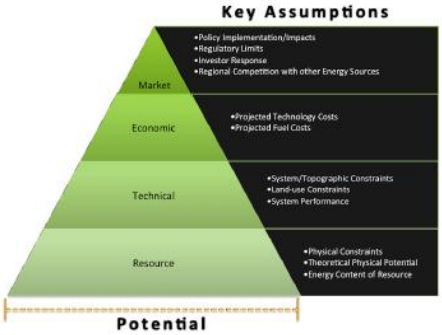


Figure4. Levels of Solar Energy Potentials Assessments [26,28]

Thus, based on the previous works that were done in various countries the methodology used in this study is built. The methodology is aimed at assessing the solar energy potential that can be extracted for future energy generation mix in Zambia. The approach considers solar radiation, sunshine hours, available and suitable land areas for PV implementation and system performance [1, 27]. The procedure involved four main steps and for analysis of the data, both simulation and analytical approach were adopted in this study.

Firstly, using ArcGIS the study area were divided into small Zones. Zambia is located at latitude 8 to 18 degree north of the equator and longitude 22 to 34 degrees east of prime meridian. Thus, for thorough assessment of the solar energy potential and its distribution within the country, the study area were divided into 130 zones, then several satellite datasets i.e. solar datasets were extracted within each zones from several points (square) which was made up of latitude and longitude [5].

Thereafter, data were prepared in excel for use in ArcGIS for spatial analysis, for solar source distribution assessment. The restricted areas for RET implementation were also extracted from various literatures [1, 29]. For simulation, both ArcGIS and Photovoltaic GIS software and analytical approach (excel) were used.

The outcomes of this study were the solar energy potential and its distribution within Zambia. To quantify the solar energy potential and its distribution within Zambia, the following factors were used; the Monthly average solar radiation [1,2,4,21,30,31,32,33]. Monthly and Yearly Solar Energy Potential [21,31], Solar Power density, Total Yearly Sunshine hours [1,31], Theoretical solar energy potential for Zambia[21] and Technical power and generation solar energy potential [1,21,26] in Zambia considering available area for solar energy and other factors that affect PV technologies.

The final step involved analysis of the results to form the conclusion on the solar energy potential and its distribution in Zambia.

3.1. Theory/Calculation Models

3.1.1. Array Model

The technical solar energy potential is the energy produced by the arrays taking into consideration the efficiency of the PV technology and some other factors such as losses due to weather condition i.e temperature and dirt covering the module, and the losses due to power conditioning[16]. Therefore, the energy available for supply to grid has been calculated using (1) given as:

$$E_{AC} = A_{PV} \cdot H_R \cdot \eta_p (1-\lambda_p)(1-\lambda_C) \quad (1)$$

Where E_A is Energy output of PV system (kWh/year) A_{PV} is Array Area (m^2), H_R is solar radiation on the module (kWh/m^2-year), η_p is module efficiency, λ_p is miscellaneous module losses (i.e due to dirt covering assumed at 10%), and λ_C is Power conditioning losses, assumed at 5%.

Module efficiency is a function of its nomial efficiency, η_r which is measured at a reference temperature T_r=25^{0}C [16]. İt is calculated as:

$$\eta_p = \eta_r \cdot [1-\beta(T_C - T_r)] \quad (2)$$

Where β is temperature coefficient for module efficiency, T_c is module temperature, T_r is reference temperature.

Module temperature is related to the average monthly ambient temperature T_a [16,17] as given below:

$$T_C = 30 + 0.0175(Gt - 300) + 1.1(Ta - 25) \quad (3)$$

Where G_t is Solar irradiance (W/m^2), T_a is ambient Temperature (^{0}C), NOCT is Nominal Operating Cell Temperature, it depends on type of module used, and T_a is ambient temperature (^{0}C).

3.1.2. Capacity Factor Model

The capacity factor is a model used to show the amount of energy delivered by an electric power generation system [4]. It is defined as the ratio of the output actual annual energy generated by PV system to the amount of energy the PV system would generate if it is operated continuously at full rated power for 8760 hours in a year and it has been evaluated using (4) [4,26]

$$CF = \frac{E_{AC}}{8760 \times P_{PV}} \quad (4)$$

Where CF is capacity factor (%), E_{AC} is Actual annual energy output (kWh/year), and P_{PV} is Full rated PV power (W_p).

3.1.3. Solar Energy Potential Model

A. Theoretical Potential Model

Theoretical solar enrgy potential involves the assessment of the solar energy that is received on the surface of the study area. This potential involves identifying the study area boundary and the size of the study land area, including annual average daily solar radiation magnitude. Thus, the theoretical potential has been calculated using (5) as expressed below;

$$E_{TH} = A_S \cdot H_P \cdot T_{TSH} \quad (5)$$

Where E_G is Theoretical Solar energy potential (MWh/year), A_{ADS} is Active Surface Area (km^2), H_R is Solar Irradiance (MW/km^2), and T_T is Yearly total Sunshine hours (hours/year)

B. Geographical Potential Model

Geographical solar energy potential involves assessing the solar energy that is received on the available and suitable land area[21]. Thus, the process of assessing this potential involves firstly excluding the restricted land areas for solar energy technologies deployment and development such as agriculture areas, roads, surface water bodies areas, protected national parks, game reserves and forest reserves, areas under the transmission and distribution line and unsuitable land area for solar energy technologies deployment and development such as lands with bad slopes of more than 3% slopes, the unsuitable area has been estimated at 566,493km^2 according to literatures [21,26]. Therefore, the remaining land area is taken as the most suitable land area for solar energy technologies deployment. Thus, the geographical solar energy potential has been estimated using (6) as given below.

$$E_G = A_{AOS} \cdot H_R \cdot \quad (6)$$

Where E_G is Geographical Solar energy potential (kWh/year), A_{ADS} is Available Suitable Area (m^2), and H_R is Total average yearly solar radiation (kWh/m^2-year)

C. Technical Potential Model

Utility-scale photovoltaic is define as a large-scale PV power plant that can be deployed within the boundaries of the country on an open space [26]. The process of assessing the extractable energy potential from the sun for any country involves firstly by excluding areas not suitable for this technology within the defined boundaries[21,26]. Considering the estimated geographical potential and technical characteristics of PV generation systems to convert the solar energy to electrical energy, the country's available technical solar energy potential can be estimated as using (7) below[21,26]:

$$E_T = A_{AOS} \cdot p_{PD} \cdot CF \cdot T_{TSH} \quad (7)$$

Where E_T is Solar Energy Potential (MWh/year), A_{ADS} is Study Area Available Suitable Area (km^2), P_{PD} is Study Area Power density (MW/km^2), CF is Study Area Capacity factor (%), and T_{TSH} is total hours in a year (8760).

4. Results and Discussion

Fig. 5 shows that the solar source across the country is not evenly distributed as it is a case in most countries due to geographical differences. However, most of the districts in Zambia receives higher annual average daily solar radiations with the lowest solar radiation of 5.51kWh/m^2-day and highest of 6.23kWh/m^2-day in fewer places. Thus, it can be noted that, all the districts in Zambia have potential for deployment of any type of solar energy technologies for various applications.

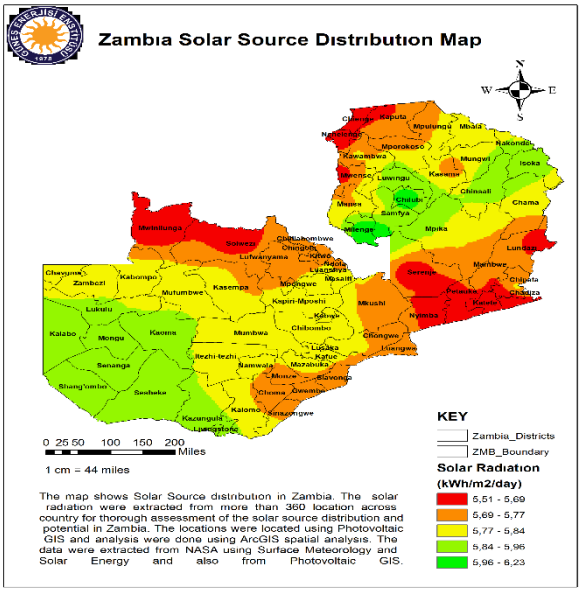


Figure 5. Solar Source Distribution and Potential in Districts of Zambia

Fig. 6 shows that most of the provinces in Zambia have radiations above country's annual average radiations of 5.78kWh/m^2-day, with Western, Southern, Northen, and part of Luapula provinces having the most attractive annual average radiation above 5.80kWh/m^2-day. It further shows that the country receives the annual solar radiation which rangs from 5.51 to 6.23kWh/m^2-day.

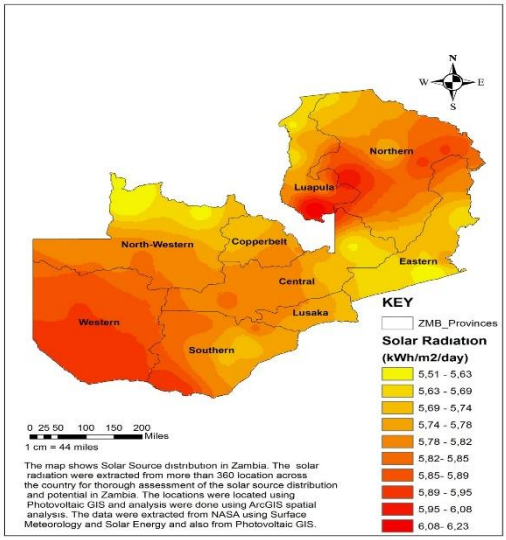


Figure 6. Spatial Annual Solar Source Distribution for Zambia

The study of monthly variability of solar radiation in the Provinces and Zambia is very important for planning the power grid management and monthly generation mix [21]. Fig. 7 compares the provincial variability of monthly average daily solar radiation. It is worth to note changes in solar radiation for Luapula and Southern provinces, that while the solar radiation in Luapula start raising up, in Southern Province the radiation start droping until the month of June then it start raisiing again until October while for Luapula the radiation continues raising until months of august and september then starting droping until december. This behave shows the need of wide deployment of solar energy technologies in all provinces for optimal ultilazition of solar energy.

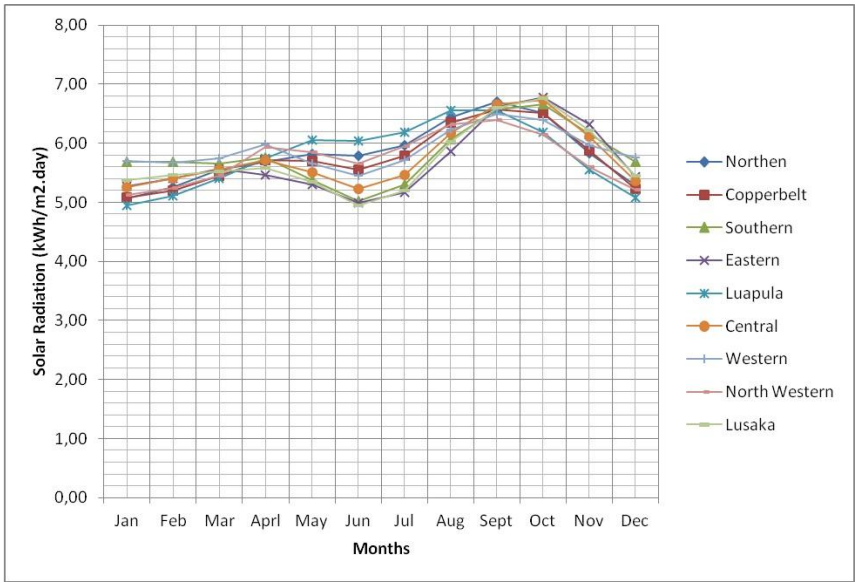


Figure 7. Comparison of Provincial Variability of Monthly average Daily Solar Radiation

Table 3. Comparison of Theoretical Potential of Solar Energy in Provinces

Province	**Total Surface area (km^2)**	**Total Yearly Average Solar Radiation (kWh/m^2-yr)**	**Total Yearly Average Sunshine Hours (hr/yr)**	**Solar Power Density (MW/km^2)**	**Theoretical Solar Power (TW)**	**Theoretical Solar Energy Potential (TWh/yr)**
Luaska	21,896	2080,50	4405,55	472,25	10.340	45,555
Luapula	50,567	2111,26	4401,90	479,62	24.253	106,759
Central	94,394	2103,01	4401,90	477,75	45.097	198,512
Copperbelt	31,328	2098,02	4401,90	476,62	14,932	65,729
Eastern	69,208	2073,20	4401,90	470,98	32.596	143,484
Western	126,386	2151,41	4401,90	488,75	61.771	271,910
Southern	85,823	2116,34	4401,90	480,78	41.262	181,631
Northen	147,186	2126,73	4405,55	482,74	71.053	313,028
North Western	125,826	2093,54	4405,55	475,21	59.794	263,425
Zambia	**752,614**	**2109,97**	**4403,12**	**479.19**	**360.645**	**1,587,963**

Table 3 above shows the theoretical solar energy potential in the different provinces of Zambia. It can be noticed that Northern Province, despite having lower yearly radiation as compared to Western Province, it has highest theoretical solar energy potential which is due to its larger surface area.

Fig. 8 below shows the provincial and monthly variability of highest Monthly average solar radiation in Zambia.It can be noticed that the month with the highest solar radiation across the Zambia changes monthly and with location, this therefore shows the importance of need to distribute the solar energy technologies across the country in order to optimize the solar energy potential.

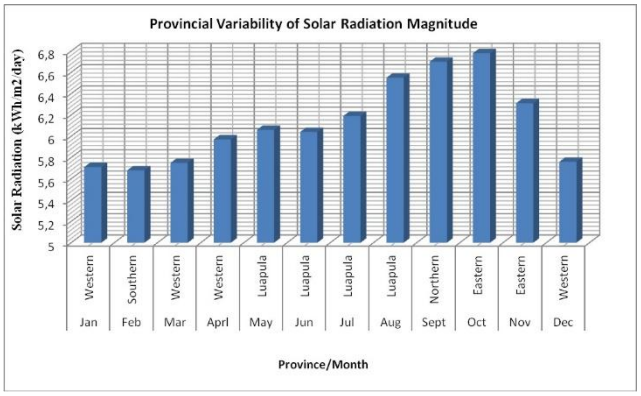


Figure 8. Provincial and Season Variability of Highest Solar Radiation

Most of the provinces in Zambia have high solar radiation (fig. 9) above 5.7kWh/m^2-day except Eastern and Lusaka provinces.

Thus, the country can be classified into three regions, low radiation regions with radiations below country's annual average daily solar radiation of 5.78kWh/m^2-day, medium radiation regions with average radiations same as the country's annual average solar radiation of 5.78kWh/m^2-day and higher radiation regions with radiation above country's annual average daily solar radiations of 5.78kWh/m^2-day. These radiations correspond to a theoretiical energy production between 2073,20 and 2151.41kWh/(m^2-year). In addition, fig.10 shows that the country can further be divided into two regions, long sunshine hours regions with sunshine hours above 12.06hrs and short sunshine hours regions with sunshine hours below 12.06hours.

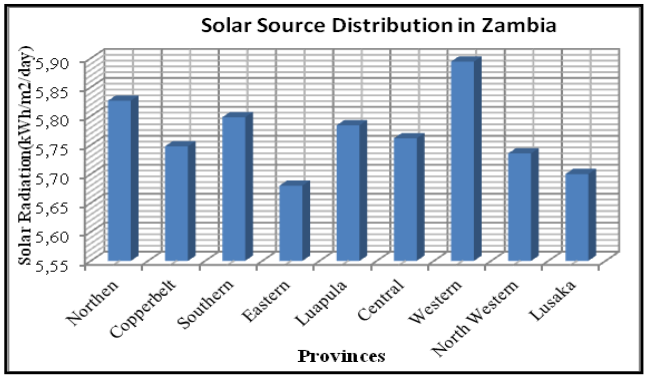


Figure 9. Provincial Annual Solar Radiation

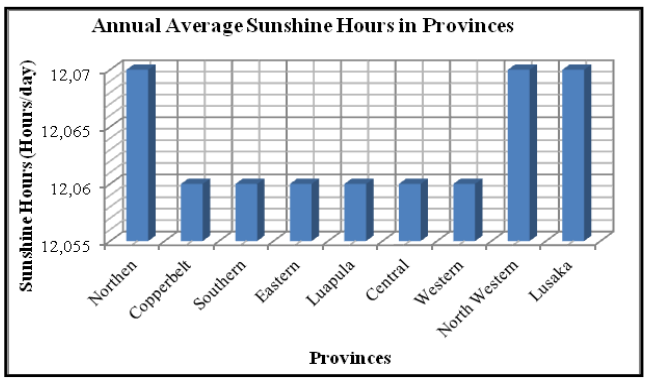


Figure 10. Provincial Sunshine hours

Fig, 11 and 12 shows the national variability of monthly average of solar radiation and sunshine hours. Table 4 shows the natioanl monthly average of daily solar radiation, sunshine hours, maximum air temperature, clearness index and wind speed. It can be noted that the country receives maixmum solar radiation, wind speed and temperatures in the months of september and october and minimum solar radiations in the months of January, June and December. While the long sunshine hours are experienced in the months of december

and shortest in June. The country has solar irradiance of 479.19W/m^2 and receives the annual average solar radiation of 5.78kWh/m^2-day and total yearly solar radiation of 2109,97kWh/m^2-year with total yearly sunshine hours of about 4403,12hours per year as shown in table 3 and 4.

Table 4. Variability of Monthly Average Solar Radiation and Sunshine hours in Zambia

Month	Sunshine Hours (hr/day)	Solar Radiation (kWh/m^2-d)	T(^{0}C)	K	Monthly Ave. Wind Speed (m/s)
Jan	12,77	5,27	25,08	0,46	2,94
Feb	12,47	5,37	25,44	0,48	2,94
Mar	12,10	5,55	25,58	0,53	2,90
Aprl	11,77	5,74	25,96	0,61	3,36
May	11,46	5,65	23,31	0,68	3,41
Jun	11,31	5,46	23,37	0,70	3,64
Jul	11,37	5,69	23,39	0,71	3,93
Aug	11,63	6,25	25,99	0,70	4,22
Sept	11,99	6,58	29,48	0,66	4,66
Oct	12,35	6,50	29,89	0,60	4,24
Nov	12,68	5,94	27,86	0,53	3,78
Dec	12,86	5,39	25,57	0,47	3,27
Annual	**12,06**	**5,78**	**26,07**	**0,60**	**3,61**
Yearly	**4403,23**	**2109,97**			

T-Average Maximum Air Temperature
K-Clearness Index

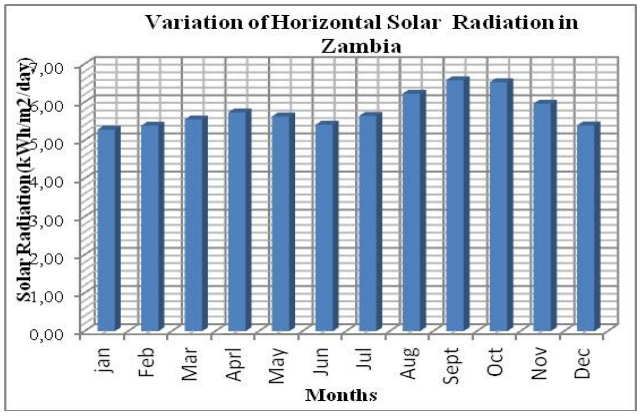


Figure 11. National Variability of Monthly Average Daily Solar Radiation

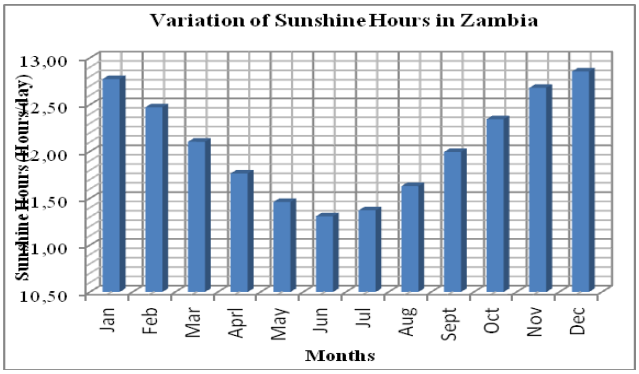


Figure 12. National Variability of Monthly Average Daily Sunshine Hours

Table 5 below presents the details of module used to analyze the technical potential.Table 6a-6b below summarizes the results of the study, showing the total estimated available area, theoretical, geographical and technical solar energy generation and capacity potential in Zambia. Zambia has on average solar energy potential of 2109,97kWh/m^2-year with average sunshine of 4403,12hours per year. It has a total suitable land area for utility-scale PV implementation of about 186,121km^2 which accounts for 24.73% of the Zambia's

total surface area. This area corresponds to geographical solar energy potential of 392,701TWh per year. Taking into consideration capacity factor which is estimated at 22.55% using Polycrystalline PV technologies and power density of 55.6MW/km^{2}the country has technical solar energy potential of about 20,442TWh/year.

Table 5. PV Module Parameters (Polycrystalline Silicon) [34]

Item	**Parameter**
PV Module Max.Power (W_P)	250
Optimum Power Voltage V_{MPP} (V)	30.3
Optimum Operating Current I_{MPP} (A)	8.25
Open Circuit Voltage V_{OC} (V)	37.3
Short Circuit Current I_{SC} (A)	8.69
PV Module Area (m^2)	1.64
PV Module efficiency (%)	15.24
Temperature Coefficient P_{max} (%/^{0}C)	-0.47
Nominal Cell Operating Temperature (^{0}C)	25

Table 6a.Solar Energy Potential in Zambia

Available Suitable Area	Annual Average	Solar Energy Potential	Sunshine Hours	Solar Power Density
km^2	kWh/m^2d	kWh/m^2a	Hrs/a	MW/km^2
186,121	**5,78**	**2109,97**	**4403,12**	**55,6**

Table 6b. Solar Energy Potential

Energy Potential	Power(TW)	Energy(TWh/a)
Theoretical	360.645	1,587,964
Geographical	89.187	392,701
Technical	10.248	20,442

5. Conclusion

The study has presented the view of the theoretical, geographical and technical potentials of solar energy and its distribution in Zambia. The data used in the study were extracted from NASA using Surface Meteorology and Solar Energy and then analyzed. The study has shown that, the country have high technical potential of solar energy for PV electricity generation and various applications. It has also presented variability and ranges of magnitude of monthly average daily solar radiation in Zambia. From the results presented in the study, it shows that the daily solar radiation in Zambia varies depending on season changes. The analyzed results also show that Western province has the highest annual average solar radiation of 5.89kWh/m^2-day while the Eastern province has the lowest radiation of 5.68kWh/m^2-day. It can be noticed that almost all the provinces in Zambia experience a good solar radiation ranges. The Western province has an annual average solar radiation range of 5.44-6.50kWh/m^2-day, while Eastern province experiences the range of 4.99-6.78kWh/m^2-day. On the other hand, the Southern and Northern provinces have an annual average solar radiation ranges of 5.03-6.66kWh/m^2-day and 5.07-6.70kWh/m^2-day respectively. Meanwhile, the Northwestern province experiences an annual average solar radiation range of 5.13-6.40kWh/m^2-day and Central province receives an annual average solar radiation range of 5.23-6.74kWh/m^2-day. Furthermore, the Copperbelt province and Luapula province experiences an annual average solar radiation of ranges 5.08-6.57kWh/m^2-day and 4.95-6.55kWh/m^2-day respectively. However, the country generally, receives annual average dialy solar radiation of 5.78kWh/m^2-day at ambient temperature of 26.07^{0}C with clearness index of 0.60 and wind speed of 3.61m/s. In addition, the country experiences a total yearly average solar energy of 2109.97kWh/m^2-year with yearly total avarage sunshine of 4403.12 hours. Having the total surface area of 752,614km^2, the country has a theorectical solar energy potential of 1.59million TWh per year on the horizontal surface. The total estimated solar energy geographical and technical potential for utility-scale photovoltaic technology are 392,701TWh/year and 20,442TWh/year respectively. Zambia has higher estimated technical potential due to relatively high solar radiation, sunshine hours, good temperatures and the availability of large suitable flat land areas for PV technology deployment. With an ever increasing population, deforestation, energy demand, and droughts which is affecting the hydropower systems which is the main source for electrical energy in the country, solar energy appears to be one of the best effective solution for production of sustainable and clean energy in energy generation mix in Zambia.

Acknowledgements

The authors are grateful to University of Zambia and Turkish Government for financial support.

References

[1] LIU Guangxu, WU Wenxıang, GE Quansheng, DAI Erfu, WAN Zhıweı, ZHOU Yang, 2011,'GIS-based assessment of roof-mounted solar energy potential in Jiangsu, China',2011 Second International Conference on Digital Manufacturing and Automation.

[2] Ahmed Belhamadia, Muhamad Mansor, Mahmoud A.Younis, 2013, ''Assessment of Wind and Solar Energy Potentials in Malaysia'', 2013 IEEE Conference on Clean Energy and Technology (CEAT).

[3] L.M. Ayompe, A.Duffy, 2014, An assessment of the energy generation potential of photovoltaic systems in Cameroon using satellite-derived solar radiation datasets, Sustainable Energy Technologies and Assessments 7 (2014) 257-264, ScienceDirect.

[4] M.Pendieu Kwaye, J.Bendfeld, N.Anglani, 2015, 'Assessment of Renewable Energy Resources in Cameroon and Special Regards on Energy Supply'.

[5] Chumnong Sorapipatana, 2010, An assessment of solar energy potential in Kampuchea', Renewable and Sustainable Energy Review 14(2010) 2174-2178 ScienceDirect.

[6] Njomo D, Wald L, 2006, "Solar radiation retrieval in Cameroon from Meteosat satellite imagery using the Heliosat_2 method", Sci Technol Vis 2006; 2(1): 19-24.

[7] Gauri Singh, Safiatou Alzouma Nouhou, Mohamed Youba Sokana, 2013, "Zambıa Renewable Readıness Assessment" International Renewable Energy Agency (IRENA) 2013 report.

[8] Likonge Makai, Marta Molinas (2013). Biogas-An Alternative Household Cooking Technique for Zambia", IEEE Conference, 2013.

[9] Prof. Dr. Imasiku A. Nyambe, Miriam Feilberg, "Zambia- National Water Resources Report for WWDR3; Theme-Water in a Changing World", Repubulic of Zambia, Ministry of Energy and Water Development. Pp 6-50

[10] Index Mundi, www.indexmundi.com

[11] NWASCO, 2014,'Urban and Peri-Urban Water Supply and Sanitation Sector Report 2014'', pp 2

[12] Africa-EU Energy Partnership (2013). Zambia Power Sector Market Brief: Zambia. http://www.ruralelec.org/fileadmin/DATA/Documents/06_Publications/Market_intelligence/AEEP_Zambia_Power_Sector_Market_Brief_EN.pdf

[13] Ministry of Mines, Energy and Water Development of Zambia[MEWD] (2008). National Energy Policy. http://www.mewd.gov.zm/

[14] ZESCO (2013b) , 'Electricity Infrastructure Development for Economic Growth'', North CPD presentation. pg12

[15] http://www.zesco.co.zm

[16] J.Mahere, 2010, Integration of Facts Devices in the Zesco Power System to Improve Power Transfer Capability and Stability, Thesis for the MEng in Electrical Power Systems, Kathmandu University, Kathmandu, Nepal.

[17] Energy Regulation Board (ERB), 2010b, ''State of Infrastructure report'', Lusaka.

[18] Mabvuto Mwanza, Navaraj Karki, Nabina Pradhan, 2012,'Zesco Generation System Adequacy Assessment for the Period 2009-2030 using Probabilistic Approach'', DOI:10.2316/P.2012.760-036, IASTED 2012 African Conference-2012.

[19] H.Walimwipi, Snow Systems Zambia, 2012,''Investment Incentives for Renewable Energy in Southern Afirca: Case Study of Zambia'', International Institute for Sustainable Development (IISD) December 2012.

[20] Department of Energy (DoE), 2010, ''Draft Renewable Energy Strategy for Zambia'', Department of Energy.

[21] Yan-wei Sun, Angela Hof, Run Wang, Jian Liu, Yan-jie Lin, De-wei Yang, 2013''GIS-based approach for potential analysis of solar PV generation at the regional scale: A case study of Fujian Province'' Energy Policy 58 (2013) 248-259, ScienceDirect.

[22] United Nations Industrial Development Organization, 2009, 'UNIDO and Renewable Energy; Greening the Industrial Agenda' Vienna, 2009.

[23] Kasanga Chiwama, et al ,2012,''Feasibility Study of Domestic Biogas Programme in Zambia'' SNV and Hivos Private Dutch Development Agencies.

[24] REA(Rural Energy Agency),2008,'Pre-feasibility Study Chilinga Hydro, Memo 2008-078, ECON-ESD pp.39

[25] Mwansa Kaoma, Shadreck Mpanga, Mabvuto Mwanza, Mundia Muya, Donat Ngendo, Ackim Zulu, et al, 2015,'State of Renewavble Energy Technologies in Southern African''International Conference on Clean Energy for Sustainable Growth in Developing Countries, September 16-18 2015, Palapye, Botswana

[26] Anthony Lopez, Billy Roberts, Donna heimiller, Nate Blair, Gian Porro, 2012,''U.S Renewable Energy Technical Potentials: A GIS-Based Analysis'' Technical Report NREL/TP-6A20-5146, July 2012.

[27] Ottmar Edenhofer, Ramon Pichs-Madruga, Youba Sokona, 2012''Renewable Energy Sources and Climate Change Mitigation: Summary for Policymakers and Technical Summary''. Special report of the Intergovernmental Panel on Climate Change IPCC, 2011, Intergovernmental Panel on Climate Change, ISBN 978-92-9169-131-9.

[28] DOE Office of Energy Efficiency and Renewable Energy (EERE). (October 2006 updated January 2011).''Report to Congress on Renewable Energy Resource Assessment Information for the United States.'' January 2011 (EPACT) Prepared by the National Renewable Energy Laboratory.

[29] Doug Dahle, Dennis Elliott, Donna Heimiller, Mark Mehos, Robi Robichaud, Marc Schwartz, et al, 2008,''Assessing the Potential for Renewable Energy Development on DOE Legacy Management Lands''. NREL, DOE/GO-102 008-2435, February 2008

[30] Pourian Alamdari, Omid Nematollahi, Ali Akbar Alemrajabi, 2013,' Solar energy potentials in Iran: A review' Renewable and sustainable energy reviews 21 (2013) 778-788, ScienceDirect.

[31] Serhat Sensoy, Yusuf Ulupinar, Mesut Demircan, Ilker Alan, Zuhal Akyurek, Pinar A.Bostan, 2010, 'Modeling Solar Energy Potential in Turkey'.

[32] Rodrigo A. Escobar,Alberto Ortega, Cristian Cortes, Alan Pinot, Enio Bueno Pereira, Fernando Ramos Martins, et al, 2014'' Solar Energy Resource Assessment in Chile: Satellite estimation and ground station measurement'', Energy Procedia 57 (2014) 1257-1265, ScienceDirect.

[33] Anwar Mustefa Mahmud, Mulu Bayray Kahsay, Asfafaw Hailesilasie, Ftwi Yohanness Hagos, Petros Gebray, Hailay Kiros Kelele, et al, 2014'' Solar Energy Resource Assessment of the Geba Catchment, Northern Ethiopia'', Energy Procedia 57 (2014) 1266-1274, ScienceDirect.

[34] http://www.alibaba.com/product-detail/High-efficiency-good-price-pv solar_1824340428.html?spm=a2700.7724838.30.26.KvgWT1&s=p

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 117~123
Available online at: http://pen.ius.edu.ba

Elongata Sy Hu In Function of Improving the Quality of the Environment

Zehrudin Osmanović[1], Samira Huseinović[2], Sanida Bektić[2], Semir Ahmetbegović[3]

[1] University of Tuzla, Faculty of Technology, Department of Chemical engineering
[2] University of Tuzla, Faculty of Sciences and Mathematics, Department of Biology
[3] University of Tuzla, Faculty of Sciences and Mathematics, Department of Geography

Article Info

Article history:

Received Jan 17th, 2017
Revised June 15th, 2017
Accepted June 17th, 2017

Keyword:

Air quality
Air pollution
Pollutants
Paulownia elongate
Lukavac
Tuzla

ABSTRACT

Interest in paulownia got its momentum around the world. With its fast-growing nature and large leaf surfaces this species can absorb significant amounts of sulfur dioxide and dust particles.
The cities of Tuzla and Lukavac, as most other Bosnian-Herzegovinian towns, have a number of geo-ecological problems, and the most pronounced one is negative anthropopressing on the atmospheric complex and pedospheric cover. This area, especially during the winter period, has a disrupted air quality where the greatest polluters are individual heating places, transport, industry, and energy sector. The pedologic cover of the wider area of Tuzla and Lukavac has suffered significant changes and is largely devastated. The processes of destruction of soils lead to complete destruction or formation of a new land with modified characteristics. High rainfall is a major cause of destabilization of slopes, but also is the negative anthropogenic activity in the area. Landslides have caused significant material damages, particularly in the residential structures of slope zones of the mentioned cities and suburban areas. This paper presents the basic biological characteristics of woody species paulownia elongata, and the possibility of planting it in areas that are now unused so to improve the quality of air, as well as on surfaces that are threatened by landslides.

Corresponding Author:

Samira Huseinović,
Department of Biology,
Faculty of Natural Sciences and Mathematics
University of Tuzla,
Univerzitetska 4,75 000, Tuzla, Bosnia and Hercegovina
Email: samira.huseinovic@untz.ba

1. Introduction

The area of Tuzla City and Lukavac municipality is located in the basin of Spreča and its right tributary Jala, in the region of northern Bosnia, or more accurately in the sub-region of Spreča-Majevica with Semberija, in the northeast of Bosnia and Herzegovina. This field has pronounced air pollution, and other geo-ecological problems as well, of which the most important are: water pollution, degradation of agricultural land, and the emergence of numerous landslides. The subject of this research is the analysis and assessment of environmental quality in the city area of Tuzla and the municipal area of Lukavac. The first task of the research is determining the level of air pollution by individual pollutants; their comparison with the permissible concentrations and limit values, as well as providing guidelines for remedial of the quality status of atmospheric complex. Another task of the research is identifying factors for reactivation of old landslides and the emergence of new ones, especially on slopes with increased human activity.
This paper hypothesis is: The state of air quality and soil cover, deteriorated by industrial production in the industrial area of Tuzla and Lukavac and by other anthropogenic activities, can be significantly improved by

biological methods, i.e. by establishing bioparks with selected plant species. The above derives six sub-hypotheses which are:

1. The state of air quality in Tuzla and Lukavac is not at a satisfactory level;
2. *Paulownia* is a plant that with its biological cycle has a positive effect on the atmospheric complex;
3. *Paulownia* is a wood species that can be used as an alternative fuel in industrial production, thereby reducing emissions of adverse gases;
4. Paulownia is a major consumer of CO_2;
5. The areas of Tuzla and Lukavac have considerable surfaces of unused land, and favorable climatic conditions for planting out paulownia;
6. *Paulownia elongata*, with its root system, can have a positive impact on the stability of slopes.

2. Material and Methods

This work consists of theoretical and practical parts. In the theoretical part are defined biological and physiological characteristics of *Paulownia elongata* S.Y. Hu. The practical part of the work includes several scientific methods and procedures. The statistic method is used to process data obtained from the established monitoring of air quality, then the comparative method is used for comparing the air quality data measured at measuring stations, also used for data comparison between earlier periods and new values and for comparing the value with the legal limits. The method of field research is applied when considering pedogeographic traits and seeing how the use of certain soils. In addition to the above, the paper used a cartographic method to obtain the data about the area.

We carried out experiments and laboratory studies in the evaluation of the calorific value of *Paulownia*. Also, we implemented field observations, that is, made direct observation of the terrain and visited the nursery that grows the mentioned species.

3. Research results

3.1. Some geo-ecological problems of Tuzla and Lukavac

The area of Tuzla and Lukavac, especially in winter period, has got damaged quality of air, but the biggest polluters are individual heating places and boiler-rooms, transport, industry and energy sector. As the mentioned urban areas are located in a valley, in periods of unfavorable weather conditions, the area is naturally predisposed to air pollution. The biggest problem is the increased concentration of SO_2 and fly ashes, due to the widely spread usage of coal (brown coal and lignite).

Based on the determined average annual values of SO_2 in Tuzla, it appears that concentrations of this pollutant generally exceed the legally prescribed annual limit value of 50 $\mu g/m^3$. Following the movement of this pollutant, we can notice that it varies from year to year, falling and rising. Very high average annual values of SO_2 were determined in 2008 (112.10 $\mu g/m^3$), 2011 (116.36 $\mu g/m^3$) and 2013 (84.15 $\mu g/m^3$), indicating that the city's inner core was highly contaminated by this pollutant. Fly ashes are considered key indicators of air quality. From the data on average annual concentrations of dust deposits in Tuzla, it is evident that their value in all years is well above the prescribed annual limit value (25 $\mu g/m^3$). The highest average annual concentration of this pollutant was recorded in 2011 and amounted to 86.40 $\mu g/m^3$ [3].

In the analyzed period (2005-2014), SO_2 concentrations were significantly increased in Lukavac too. During this period the hourly values of warning threshold were exceeded eight times, and the value of alert threshold 20 times. The concentrations of NO_2 in the area of Lukavac, similarly to the values of SO_2, increased during the cold period of the year; however in the analyzed period were not recorded hourly exceedings over the threshold of warnings and alerts for this pollutant. The concentration of carbon monoxide (CO) reached high values during the entire monitoring period. The content of CO was increased in autumn and winter [1].

The concentration of deposited dust ($PM_{2,5}$) was increased during the colder period of the year, i.e. during the heating season, which indicates that the main reason for the high content of deposited dust is its emission from individual heating places and boiler-rooms. It was noted that the alert threshold was exceeded 3 times, and the value of $PM_{2.5}$ reached the alert threshold 2 times. It is estimated that 1.337 households have individual boiler-rooms and that they spend ten tons of lignite and six m^3 of wood in one heating season, warming the total residential area [4, 7, 21].

Anticyclonic weather situations in the colder times of the year also affect the air quality. Then there are frequent occurrences of fog, mist and temperature inversions, which contributes to the retention of pollutants in the ground layer of air. Smog rises to the height of the inversion layer and forms a smoke screen.

The modern period of this region is marked by closely related processes of urbanization and deruralization characterized by industrialization and deagrarization. These very processes of urbanization, industrialization and deagrarization have contributed most to pollution, degradation and devastation of soils in this area. Pollution and devastation of the soil can be the consequence of several causes, namely: biological contamination (infection), chemical contamination, anthropogenic degradation and physical destruction of land [18].

Thus, in the area of Tuzla city there is 40.75 km^2 in landslides, or 13.44%, and under unstable slopes is 29.97 km^2 or 9.89% of the total area. In total, landslides and unstable slopes cover 70.72 km^2, or 23.33% of the total area of Tuzla city, which is a problem of enormous proportions for the population and housing, as well as to the very quality of pedologic cover. According to the Cantonal Administration of Civil Protection of TK, in the city of Tuzla in 2014 were registered 2,170 landslides [21].

The highest number of landslides appeared in the eastern and central part of the city area (known as "municipal area" by 2014) where occurred landslides that threatened material goods, with a lesser risk of endangerment of human life. The landslides were formed on slopes with inclination, mainly between 5° and 30°. Human activity had been expressed on these slopes, that is: the forest vegetation was removed, a number of suburban and rural settlements were built (those that do not have adequate infrastructure), and a large number of buildings were made without building permits. The terrain is further destabilized by cutting the slopes, during treatments of soil or inadequate agricultural production [1].

3.2. Biological characteristics of Paulownia (*Paulownia elongate* SY Hu)

The tree *Paulownia elongate* SY Hu reaches a height of over 10 meters, with a wide conical crown. The leaves are large, green, their lower surface pubescent.

Paulownia wood has the color of honey. It produces small seed, 1.4 mm to 3 mm, located in pods. The pod has oval shape and it is woody, with a size from 2.5 to 5 cm (Figure 1). It is a noninvasive type that also thrives in very sparse soil [11].

Figure 1. Paulownia elongata SY Hu

Because of the high percentage of tannin it has developed a resistance to various pests, hence protection against insects and diseases is almost not needed. Paulownia elongata is a hard wood, but at the same time it is the lightest known wood weighing 272 to 336 kg/m^3 (average 304 kg/m^3).

The wood is light in color and almost without knots, with resistance to bending and twisting making it perfect for carving. Fire-resistant point - the point of lighting is twice the size of pine's, which is especially interesting for coastal areas which are in summer exposed to increased risk of fire [12]. *Paulownia* wood swells very little. The change in volume with change of 1% moisture amounts to 0.290%, while with the poplar that coefficient is 0.397%, and with beech and oak 0.550% and 0.592%, respectively. These results indicate that the paulownia wood is very stable in variable climatic conditions (Figure 2).

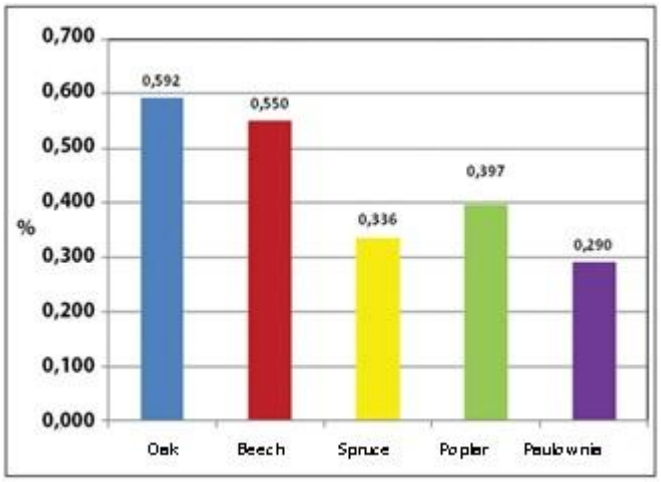


Figure 2. Percentage of wood volume change with the moisture change of 1%

Paulownia tree is a "small manufacturer" of heat taking into account a cubic meter of wood biomass. By comparison, 1 m^3 of *Paulownia* with the humidity of 15% gives about 1069 kWh of thermal energy, while the same amount of oak in combustion produce almost twice the energy - 2,363 kWh. These results are a consequence of lower density *Paulownia*, but also the fact that 1 kg of any tree of the same moisture content gives about the same amount of heat energy because the chemical composition of all kinds are about the same.

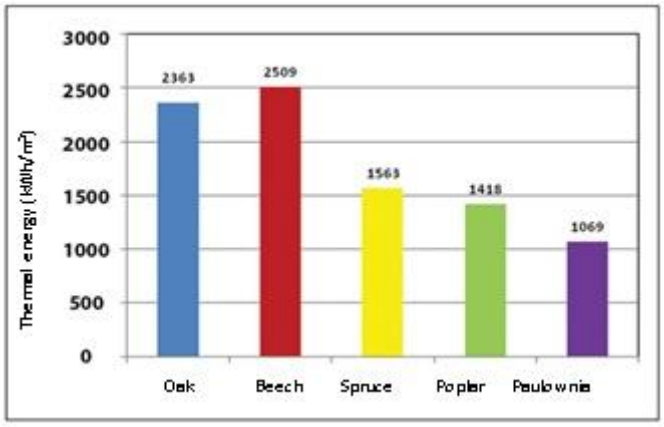


Figure 3. Thermal energy (in kWh) obtained by burning 1 m^3 of wood (moisture content 15%)

Table 1. Elemental analysis of the species Paulownia elongata

	Paulownia elongata
dry matter	25,52
organic matter	16,24
C	43,68
N	2,74
C: N	15,83
pH	5,46

Table 1 presents the elemental analysis of the species *Paulownia elongata*. The possibility of using *Paulownia* in industry is wide. It can be used as technical wood, but also as an alternative fuel with significantly lower emissions of SO_2 [10]. (Table 2).

Table 2. Paulownia as an alternative fuel

Type of energy source	SO_2(t/day)			CO_2(t/day)		
Coal	1,73			206,34		
70 % coal +30 % alternative fuel	Coal	Alternative fuel		Coal	Alternative fuel	
	1,21	0,66		144,44	65,23	
	1,87			209,67		
70 % coal +30 % (15 % alt. fuel +15 % paulownia)	Coal	Alternative fuel	Paulownia	Coal	Alternative fuel	Paulownia
	1,21	0,33	0,02	144,44	32,65	32,61
		0,35			65,27	
	1,56			209,71		
70 % coal +30 % paulownia)	1,21	Paulownia		144,44	Paulownia	
		0,03			65,31	
	1,24			209,75		

4. Discussion

KYOTO program of environmental protection ranks *Paulownia* in the first place among the plants, like a mine of oxygen and air cleaner. Given that it is harder and harder to follow the prices of energy sources we use every day and that are in constant increase due to reduced reserves, *Paulownia* as a wood biomass presents an energy source that renews itself, because after cutting it grows back from the stump. Additionally, Paulownia gives high calorific value of 4,700 kcal / kg with negligible sulfur content during combustion. The whole planet seek to reduce greenhouse gas emissions, and *Paulownia* absorbs significantly more CO_2 than other tree species (eg. 4 acres of *Paulownia* absorbs in one year up to 13 tons of CO_2 from the atmosphere and it affects climatic changes).

Thanks to the large leaf surface and the fact that the underside of the leaf has dense hair, this species can absorb significant amounts of sulfur dioxide and dust particles. Results of the analysis of heavy metals (Zn, Fe, Pb, Cu, Ni, Cr, Mn, Cd, As, Hg) in the leaves of woody species *Paulownia elongata* SY Hu growing in urban areas clearly show that *Paulownia elongata* SY Hu is a tolerant species, and can be recommended for forming tree lines along urban and regional roads as well as for the formation of wind protection zones along the main roads [5, 17]. *Paulownia* can absorb heavy metals from the soil and from the air.

Heavy metals in the soil may be the result of natural pedogenetic processes [20], as well as of anthropogenic factors that lead to environmental pollution. A very important source of heavy metals and other polluters of soil and plants is traffic [8, 14]. Plants bring in heavy metals constantly during the vegetation period. The highest values are reached at the end of the growing season [6, 15]. Also, there are many literature references that point to the impact of heavy metals on morphological, anatomical and physiological characteristic of woody species among others [9]. Species of the genus Paulownia, according to many literature data, indicate the possibility of adopting heavy metals [13, 19]. The level of tolerance of this species to pollution of air, is the basis for its development and survival in the urban environment.

Paulownia species are very suitable for decoration and enriching environment, and the need of reforestation. They are also equally suitable for landscaping of urban and industrial areas [22].

Paulownia is a tree that has the capabilities of very high intake of nitrates, heavy metals and other elements from shallow and deep layers of the earth. It has a unique root system where the roots grow at a depth of over 2m. Due to, even several meters deep rooting system, it is used for the rehabilitation of landslides. Such a root system, in combination with the rapid growth of paulownia enables interchange of much more nutrients as opposed to other species, thus giving a great potential in bio-remediation of contaminated soil.

Paulownia also has a significant role in the rehabilitation and protection of soil from erosion. Usable surfaces for planting paulownia, in the area of Tuzla and Lukavac, are: free farmlands, conditionally stable and unstable slopes that have got developed (standard) soil, lands of industrial zones that are not occupied by infrastructure facilities, as well as areas with present surface mining of mineral raw materials, and tailings dumps with prior soil reclamation.

By surface mining of coal and other mineral resources, vast areas were degraded. An example is the Tuzla and Zenica coal basin. In accordance with legislation that treats the exploitation of mineral resources and

environmental protection, mines are required to recultivate degraded areas, however, it is not the practice in our country.

5. Conclusions

Based on the conducted analyzes, it was concluded that in Lukavac, as well as in other industrial cities in Bosnia and Herzegovina, air quality is not at a satisfactory level. Particularly expressed is increased concentration of SO_2 due to extensive use of fossil fuels.
Paulownia is a plant that with its biological cycle has a positive effect on the atmospheric complex.
Because of its high growth rate, this wood has a high ability to absorb carbon.
With biological methods, that is, by planting the selected plant species, the status of air quality in the industrial zone of Tuzla and Lukavac can be significantly improved.
Paulownia elongata SY Hu has a large degree of tolerance to air pollution, which is the basis for growing and survival in urban conditions.
This type of wood can be used as an alternative fuel in industrial production, thereby reducing emissions of adverse gases, and is a major consumer of CO_2.
Paulownia has an important role in land reclamation and protection of soil from erosion, and because of its deep root system it can have positive impact on the stability of slopes.
The area of Tuzla and Lukavac has considerable surfaces of unused land and favorable climatic conditions for planting Paulownia, or establishment of bioparks which would have economic, environmental and educational function.

References

[1] Ahmetbegović, S. i Gutić, S. (2015): Stanje kvaliteta zraka u Lukavcu, Naučna konferencija "Kulturno-historijsko i prirodno naslijeđe općine Lukavac", Javna ustanova biblioteka Lukavac i Zavod za zaštitu i korištenje kulturno-historijskog i prirodnog naslijeđa Tuzlanskog kantona, Lukavac, 31.10. 2015.

[2] Ahmetbegović, S., Stjepić-Srkalović, Ž., Gutić, S. (2015): Poplave i klizišta na području Grada Tuzla uzrokovani prirodnim nepogodama u 2014. godini, Acta geographica Bosniae et Herzegovinae, Vol. 2, No. 4, Udruženje geografa u Bosni i Hercegovini, GEOuBiH, Sarajevo, (el. izdanje)

[3] Gutić i sar. (2015): Kvalitet zraka u Tuzli, Acta geographica Bosniae et Herzegovinae, Vol. 3, No. 5, Udruženje geografa u Bosni i Hercegovini, GEOuBiH, Sarajevo, (el. izdanje)

[4] Izvještaj o stanju okoliša općine Lukavac, 2012.

[5] Knežević et al (2009): Concentrations of heavy metals in soil and leaves of plant species Paulownia elongata S.Y.Hu and Paulownia fortunei Hemsl African Journal of Biotechnology Vol. 8 (20), pp. 5422-5429.

[6] Krstić B., Stanković D., Igić R., Nikolić N. (2007) Biotechnol. & Biotechnol. Eq., 21(4), 431-436.

[7] LEAP, Akcioni plan zaštite okoliša općine Lukavac, Lukavac, 2011.

[8] Memmon, A., Aktoprakligil, D., Özdemir, A., Vertii, A. (2001): Heavy metal accumulation and detoxifikation mechanisms in plants. Turk. J. Bot. 25: 111-121.

[9] Nikolić, N. (2009): Effects of heavy metals on morpho-anatomical and physiological characteristics of poplar clones (Populus sp.) Doctor thesis. Faculty of Sciences, Novi Sad, Serbia.

[10] Osmanović, Z., Haračić, N., Zelić, J. (2016): Analiza mogućnosti upotrebe paulownije (*Paulownia elongata*) kao alternativnog goriva u cementnoj industriji u cilju smanjenja emisije polutanata. XI Naučno-stručni simpzij sa međunarodnim učešćem , Zenica 21.-22. april 2016. godine

[11] Osmanović, Z., Huseinović, S., Osmanović, S., Ahmetbegović, S., (2016): Construction of the biopark on the devastated land in urban areas. International Symposium on Environment and Morality, 4-6 November, Alanya – Turkey

[12] Popović, J., Radošević, G. (2008): Anatomsko- hemijske karakteristike drvnih vlakana vrste Paulownia fortunei seem. Hemsl.Šumarstvo 4. Beograd. 71-77.

[13] Shaw, A.J. (1990): Heavy Metal Tolerance in Plants: Evolutionary Aspects. In: CRC Press (Ed.), pp. 39-53.

[14] Stanković, D. (2008b): Biljke i saobraćaj. Monography, p. 1-98. Zadužbina Andrejević., Beograd.

[15] Stanković, D., Krstić, B., Igić, R. (2005): Sadržaj mangana u zemljištu i lišću nekih vrsta drveća u NP ‘’Fruška gora’’. Glasnik šumarskog fakulteta, 91, 207-217.

[16] Stanković, D., Krstić, B., Nikolić, N. (2008a): Effect of trafic on the soil contamination with polyciclyc aromatic hydrocarbons (PAHs). J. Biotechnol. Biotechnol. Equip. 22(2): 736-741.

[17] Stanković, D., Nikolić, M.S., Krstić, B., Vilotić, D. (2009): Heavy Metals in the Leaves of Tree Species Paulownia Elongata S.Y.Hu in the Region of the City of Belgrade. Biotechnology & Biotechnological Equipment, 23:3, 1330-1336.

[18] Stjepić Srkalović i sar (2016): Način korištenja, ugroženost i devastacija tla na području grada Tuzla, Zbornik radova Prirodno-matematičkog fakulteta, Univertiteta u Tuzli, Svezak geografoija, Godina XII, Broj 12, Tuzla;

[19] Wang, J., Zhang, CB., Jin, ZX. (2009): The distribution and phytoavailability of heavy metal fractions in rhizosphere soils of Paulowniu fortunei (seem) Hems near a Pb/Zn smelter in Guangdong, PR China. Geoderma, 148(3-4): 299-306.

[20] Woolhouse, HW. (1983): Toxicity and tolerance in the response of plants to metals. In: Encyclopedia of Plant Phisiol., New Series, Vol. 12 C, Springer-Verlag, New York, Heidelberg, Berlin, pp. 246-289.

[21] Zbirni izvještaj o procjeni šteta na materijalnim i drugim dobrima izazvanim djelovanjem prirodnih nepogoda na području Tuzlanskog kantona u 2014. godini, Kantonalna komisija za procjenu šteta od prirodnih i drugih nesreća, Tuzla, januar 2015. godine;

[22] Zhao-Hu, Z. et al. (1986): Paulownia in China: Cultivation and utilization by Chinese academy of forestry staff; Asian network for biological sciences and international development research centre.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 124~127
Available online at: http://pen.ius.edu.ba

Development of Computer-Aided Industrial Design Technology

Enes Akca
Department of Mechanical Engineering, Faculty of Engineering and Natural Sciences, International University of Sarajevo

Article Info

Article history:

Received Jan 23rd, 2017
Revised Apr09th, 2017
Accepted June16th, 2017

Keyword:

CAD
CAID
Industrial design techology

ABSTRACT

With the development of science and technology, industrial design industry also in development, and at the same time, the industrial market in the design of the products of industry, the species diversity of interest requirement also become increasingly strict. In order to ensure that the industrial design in terms of quality and quantity can better development, computer aided design of the industry establish human-computer interaction, become the key factors of industry design. This paper puts forward based on computer aided the origin of the industrial design, and then puts forward computer-aided industrial design of man-machine interaction of the concept and characteristic, and human-computer interaction application in industrial design, and finally to the future development of human-computer interaction made planning and prospected.

Corresponding Author:

Enes Akca,
Departement of Mechanical Engineering,
International University of Saraejvo,
Hrasnickacesta 15, 71210, Sarajevo, Bosnia and Herzegovina.
Email: eakca@ius.edu.ba

1. Introduction

For over a decade many of the Computer-Aided Design programs have been around, and the first traces of their impact begun over 50 years ago. Furthermore, some of the best known early engineering drawings were seen in the work of Leonardo da Vinci. While he is well known for his Mona Lisa, he was also a designer of military machines and forerunner of today's industrial machines. Leonardo's design work was artistic in nature, more illustration than engineering drawings. His work was quite advanced for the time, however, no multi-view drawings of any of his designs are known to exist today, so we can say that modern engineering started in 1950s and by that time there were dozens of people working on numerical control of different machines and programming engineering design [1]. After PRONTO, Sketchpad and other programs, by the 1970s, research had moved from 2D to 3D. Nowadays, modern CAD era consists of not just improvement in modeling and analysis but also from engineering, manufacturing to sales and marketing [2]. The future of CAD certainly means a combination of the accuracy and control of design with the speed and flexibility of precise modeling. The result is that designers spend less time planning a model's construction, they are more focused on waiting for the changes in design, and they spend less time in remodeling the design for future uses. Industrial technology, that is the central focus of the article, is very much supported by new discoveries within CAD, since wide variety of hardware and software is developed, and a variety of constantly changing technologies are attracting the industrial design talents as well. Computer-aided Industrial Design (CAID) is a software system that gives support to product development in form, color, decoration, and most importantly it is a tool for support in product innovation design. Industrial design is mostly based on marketing and economy, however with the development of new technologies the economy is going through changes as well. Customer's demand is primary, personalization, and originality are the key. To gain all that CAID is crucial, therefore it is emphasized how most companies face the trend of increasing competition and product complexity, so enterprises are enhancing cooperation and participate in dynamic manufacturing, were

computer systems can create flexible and agile manufacturing mode. To give a better understanding of the topic Yao [2] introduced with the very beginnings of CAID, the influence of the design on industry, several characteristics and problems that may occur within the CAID.

2. Effect of the Computer to Industrial Design

Industrial design is going through an expansion and aside from frequent human-computer interaction it also requires artificial intelligence technology. In the past, there was a persistent battle between the desire to implement new software techniques and the performance of available computers. That has changed in recent years as the performance of low-cost computers had its burst. During the past 40 years, price and performance percentages of available systems have increased by a factor of a million and there is no indication that the pace is slowing down. In fact it is accelerating. Software has become much stronger and there are only few design problems that cannot be freely handled today. In the design, key process is creative design thinking, where it is crucial to create the translation of the designer's conception into drawing. That is a complex process and in the world of design it is known as the stage of concept function. Another important segment is design grammar. That is the formal description method that shapes the object and its principle by refining abstract elements of the shape. It is one of the foundations of intelligent design system. In the early days of the CAD industry, system vendors had to spend considerable effort designing basic hardware components and programming foundation-level software functions. Today's computers come with all these capabilities built in and as a consequence CAD software vendors are able to concentrate their development resources on providing enhanced and more reliable applications. Some computers are equipped with microprocessors that contain dual or quad computing elements. We use chips with eight, sixteen or more processing elements, therefore CAD software, of course, has to be adapted to use these advanced processing capabilities. Booker [3] makes a firm statement, on the subject of the importance of computer, and its influence to the concept and method of industrial design. Since today we use computers to generate data model, difficulties that designers had in changing model into engineering drawing are gone, and the relationship between design and manufacturing is closer. Moreover, the CAD has shortened the entire product improvement cycle. On one hand, it increases the efficiency and the speed of the final product, on the other hand I believe that it eliminates the traditional performance in design, and many designers just go over the design without any previous excitement of creating something new. When it comes to product modeling, designer plans their final product on imagining what the final outcome will be, therefore, computer assisted cartography changes this concept and improves efficiency to avoid losses caused by corrupted design at the design stage. That brings us to the core of the article which is the very production and application of industrial design.

3. Application of CAID

CAID bring advantages for the designers since they have the freedom to express their wishes and display their creative idea. It ensures the high quality of the design through new advanced design tools that are approachable to any designer. New computer programs bring flexibility since they use high-tech tools for creative design directly on the system. Designer is able to see and implement 3D solid modeling techniques for geometric modeling of objects. They can choose a color design, form, texture, many different styles in design, and go through program evaluation and testing. It can easily be modified until the client's desires are satisfied. The system is used to optimize the design for the needs of the market. Virtual reality, neural networks, genetic algorithms and parallel design are introduced in CAID field. Currently, computer design mainly uses algorithms that include adaptive neural network and morphological differences in remaining algorithm, so that way designers are able to control the generation of the new design. Yao is stressing the fact that CAD is aside from such a huge development, a field that will go through many changes in the future. He mostly relates that with the further growth of technology. In accordance to that, industrial design will have an outbreak as well. When new technologies take their place, such as artificial intelligence, virtual reality technology etc. we must find a new way to understand the design process and the new level of thinking about design in general. CAID will make industrial design develop in the direction of expansion, integration, it will make human-computer interaction more natural, and innovative design more advanced and operative. For me one of the most interesting segments of the article was author's reference on the artificial intelligence and user interface progress. He believes that today's internet connectivity is crucial for expanding the presence of art and design space towards the broader digitization of the art design. We can be as free and say that even

without internet the presence of design is guaranteed, since like Yao said in that case the constraint is purely geographical.

Figure 1. Computer-aided design softwere system

Electronic design is the basic aspect of computer technology and it indicates a long-term research plan based upon the insights into where the technology will allow us to go over the next decade or two. Whether we want to admit or not the development of the "New World" is beginning to show its stresses with visible changes in business practice, and the shift to multi-core processors, therefore we are witnessing early manifestations of the problems ahead. Unfortunately, much less reliable technology will follow, forcing further changes in industry, design practice, software development, and if designers are unsuccessful in fully containing these problems, we will face noticeable changes in system strength and performance. The major problem remaining is applying the technology to increasingly complex projects. That means managing enormous amounts of design data, a task some companies are doing well while others are struggling.

4. Conclusion

CAID is phenomenal technology that is revolutionizing engineering design and manufacturing, especially when used right, therefore it is important to allow the further growth of new designers and new ideas.

References

[1] Cianchi, Marco, Leonardo's Machines, Edizioni Becocci, Largo Liverani, Florence, Italy.

[2] YAO, Jun, International Journal of Computer Science Issues, vol. 10, no 1, January 2013.

[3] Booker, Peter Jeffrey, A History of Engineering Drawing, Chatto & Windus 1963.

[4] Rajesh Kumar Goutam, Sanjay Kumar Dwivedi, "Search Engines Comparison on the Basis of Session Duration and Click Hits", *International Journal of Computer Science Issues*, vol. 8, no. 2, pp.179-183, 2011.

[5] WANG Hai-bo, "Computer Aided Industrial Design", *Journal of Anhui University of Technology*, no.2, pp.23-26, 2005.

[6] Johannes Behrisch, Mariano Ramirez, Damien Giurco, "Representation of Ecodesign Practice: International Comparison of Industrial Design Consultancies", *Sustainability*, vol. 3, no.10, pp. 1778-1791, 2011.

[7] G.L. Hu, X. Zhu, "Comprehensive evaluation of population, resources, environment and economic system of Xinjiang: Based on the principal component analysis", *Ecological Economy*, no. 6, pp. 67-69, 2009.

[8] S. Li, W. Qiu, and Q.L. Zhao, “Quantitative relationship between environmental quality and economic development of Heilongjiang province”, *Journal of Harbin Institute of Technology*, vol. 38, no. 11, pp. 1986-1988, 2006.

[9] Elmira Moghaddami Khalilzad, Sanam Hosseini, "Recovery of Faulty Cluster Head Sensors by Using Genetic Algorithm (RFGA) ", *International Journal of Computer Science Issues*, vol. 9, no. 4, pp. 141-145, 2012.

[10] Gert Pasman, Ingrid Mulder, "Bringing the Everyday Life into Engineering Education", *International Journal of Advanced Corporate Learning*, Vol. 4, No.1, pp: 25- 31, 2011.

[11] E. Akca, "The application of CFD to IUS buildings analysis", *Periodicals of Engineering and Natural Sciences*, vol. 4, no. 1, pp. 9-16, 2016.

[12] E. Akca, "Validation of Stresses with Numerical Method and Analytical Method", *Periodicals of Engineering and Natural Sciences*, vol. 4, no. 1, pp. 17-28, 2016.

BIBLIOGRAPHY OF AUTHORS

Enes Akca – Enes was born in Istanbul in 1990. He acquired his bachelor and graduate degrees from International University of Sarajevo in Sarajevo. He employed as academic staff at International University of Sarajevo, at the beginning of 2015, Enes is Senior Assistant at International University of Sarajevo, Department of Mechanical Engineering, PhD candidate at the same time. He is also serving administrative duties as Mechanical Engineering Laboratory Assistant of Research and Development Center at International University of Sarajevo.

Periodicals of Engineering and Natural Scinces ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 128-135
Available online at: http://pen.ius.edu.ba

Potential of air quality improvements in Sarajevo using innovative architecture approach

Maida Halilovic[1], Malik Alibegovic[2]
[1]Departement of Architecture, International University of Sarajevo
[2]Departement of Architecture, International University of Sarajevo

Article Info

Article history:

Received Feb 20th, 2017
Revised May 20th, 2017
Accepted June 16th, 2017

Keyword:

Air pollution
Air quality
Innovative architecture
Titanium dioxide

ABSTRACT

Air pollution and population health related to it is one of the main issues in Sarajevo in the past few years, especially in the winter time. Reason for that is combustion of coal, oil fuel and other harmful emissions that leads to creation of air pollutants such are: particulate matter (PM), sulfur dioxide (SO_2), nitrogen dioxide (NO_x), and creation of Ozone (O_3). This study addressed the question regarding possible solutions for improvement of air quality by removing NOx emitted from the cars in the particular area of urban core of Marijin Dvor in Sarajevo using innovative architecture approach. Basic principle introduced by this paper considered outdoor application of TiO_2 coating, in accordance with previously conducted studies. First part of research was conducted bysnowball research method which was used for accumulation of similar research material, while later study was completed using mixed method research design with explanatory research method which provided analyses, comparison and calculation of expected outcomes of applied innovative solutions as a mean to reduce pollution. These innovative approaches were implemented as coatings of TiO_2 on elevations and paved areas next to the main road. Total area covered by TiO_2 was 15 778 m^2. Results strongly indicate that usage of TiO_2 coating as innovative approach reduced the amount of NO_x emitted by cars per year by 52,39%. This amount of NO_x removed after treatment indicates that method proposed in this study was very effective and suggests that this study can contribute to further analyses and lead to possible implementation in the future.

Corresponding Author:

Maida Halilovic
Department of Architecture
International University of Sarajevo
Hrasnickacesta, 15, Sarajevo 71000, Bosnia and Herzegovina
Email: maidahalil@gmail.com

1. Introduction

Together with a growth of urban and metropolitan areas, growth of population density and transportation related activities occur [1]. According to the findings by the United Nations, in 2007 half of the world's population was living in urban areas[1]. Recent years are capturing continuous increase in the proportion of the population living in urban areas [2]. While cities during history were considered as a society's core of

[1] United Nations. World Urbanization Prospects: The 2003 Revision. New York: United Nations, 2004

innovation, richness, and development, more pessimistic aspect regarding crime, disease, and pollution was also established [3].
As a result of raising transportation, major deficiencies associated with the health and pollution are becoming unresolved. Furthermore, researchers are trying to address these problems examining and testing innovative methods and techniques. According to Durakovic, increase in energy consumption is linked with increase in consumption of non-renewable energy source [4], thus suggests development of a design based on the energy storage that will reduce building energy demand and incorporate passive design strategies [4]. Reducing energy demand is achievable through better insulation of building envelope using new materials [5][6]. Aside from innovative solutions for future design, several studies done in the recent years were analyzing performances and implementation of titanium dioxide (TiO_2) coating practices in the process of removing harmful air pollutants, by transforming them into harmless and environmentally-friendly air compounds. Air pollution in Sarajevo has been the problem over the decades, the only time without air pollution problem was the period during the war when industry stopped, heating was minimal and automobiles were scarce. During the last few years quality of air in Sarajevo is very bad and meteorologists are often "blaming" the nature for air pollution in Sarajevo: basin position and temperature inversion creates the effect of lid over the city without the air drift under it, especially during the winter months.

2. Literature review

This research addressed the question of removing NOx emitted by cars as a mean of reducing air pollution by innovative approach defined as application of TiO_2 coatings on different surfaces. In the past decade titanium dioxide (TiO_2) emerged as an excellent photocatalyst material for environmental purification [7]. Research question covered in this study was “What are possible approaches of applying TiO2 coatings in order to increase air quality and what are outcomes regarding effectiveness of this method?”
First step taken in order to answer addressed question was aggregation of already conducted studies regarding effectiveness of TiO2 coating in decreasing the amount of NO_x in the air and reviews existing applications in practice. These studies were conducted by leading company[2] in producing TiO2 products applicable in different settings, indoor and outdoor, and on different surfaces – roofs, external walls, paved areas and roads. Researchers in the United Kingdom are even creating NO_X-removing “catalytic clothing” in which TiO_2 nanoparticles and calcium carbonate are added to fabrics, sprayed onto clothes, or applied during washing [8]. Based on the studies by Cristal, 100 m^2 of surface painted with KNOxOUT may remove the NO_x equivalent to that produced by a car driven more than 130 km, which proves good effectiveness[3]. In one trial in Manila’s Guadalupe train station, Cristal Global painted 4,100 m^2 of exterior wall and found the paint removed about 26 g of NO_X per 100 m^2 of painted surface. The company claims each painted square meter could remove 80 g of NO_X per year. Other trials that run over 4 years, a wall in London of 135 m2 was treated with another Cristal product, and reported that reductions of 60% for the NOx. The photocatalytic paint is as well reported to work in the low-light environment of multistory parking lots, capturing 2.2 g of NO_X per square meter per year [8].
According to a study on evaluation of titanium dioxide in removing air pollutants [9], the removal rate for volatile organic species is about 60 cubic meters of air per day. It further states that “these numbers are rough estimates, but are based on careful quantitative investigations”[4]. The same study labels technology of TiO2 as technically feasible, but underlines the problem of cost-effectiveness, due to the fact that reducing cost will be challenging due to the large volumes of air that must be processed.

3. Methodology

This research paper was addressed as a case study with mixed-method research design and explanatory research method, where quantitative data were followed up by qualitative.
First part of research paper was obtaining and analyzing data regarding average car emissions of NOx, traffic counting for particular urban part of Sarajevo, and analyzing innovative methods regarding air quality improvements. Data was collected by snowball method and further content analysis from the records were done. Data regarding traffic counting in the proposed area of Marijin Dvor in Sarajevo used in this paper was obtained from Ministry of Transport - Directorate for Roads of Sarajevo Canton, Traffic Counting on existing

[2]Global, U. (2017, January 20). *Cristal ACTiv™*. Retrieved from Cristal ACTiv™
[3]Global, U. (2017, January 20). *Cristal ACTiv™*. Retrieved from Cristal ACTiv™
[4] [9]

Primary city and regional network of roads jurisdiction, Road Directorate Sarajevo Canton 2015, published in July 2016, while data about car NOx emissions were taken from a study by IICT (The International Council on Clean Transportation) on emissions from EU Diesel Euro 3 passenger cars, since this engine type it is mostly used in Bosnia and Herzegovina[5]. Outdoor air quality improvement was done by removing NOx from the air emitted by cars with usage of innovative approach. This approach includes application of TiO2 coats on the surfaces next to the very crowded main road in the urban core of Marijin Dvor, Sarajevo. After analyses of different studies by leading experts and companies that produce TiO_2 coatings, further research included analyses of gained results and investigation of possibilities of air purifying using TiO2 coatings in the case study of urban core of Marijin Dvor, Sarajevo.

Study proposed introducing coats of TiO_2 on five elevations and five small squares and pedestrian paved areas in mentioned urban core. Due to different classification of these elevations regarding architectural style and importance for cultural heritage, different approaches were proposed; application of TiO_2 as an elevation painting, and addition of designed architectural elevation part "Module X" that will serve as a new design in old settings method to satisfy esthetic, and as a NO_x removal with TiO_2 coating to serve air-purifying function, in the city that has constantly growing problem with air quality, mostly due to expansion of its area, population and transportation system.

4. Case-study setup

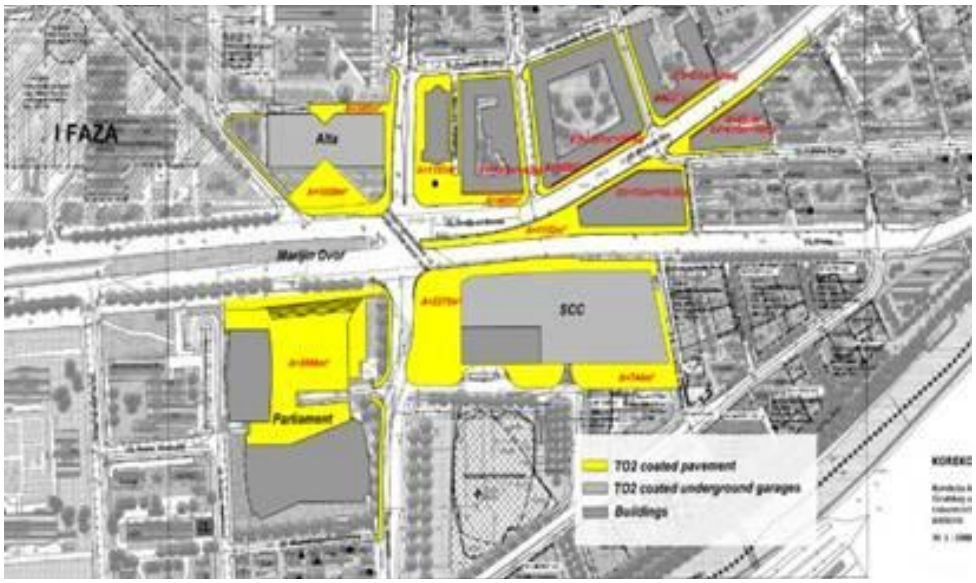


Figure 1. Map of Marijin Dvor with TiO_2 application

Air purifying was done by removing NO_x emitted by the cars from the air. It was realized by applying coatings of titanium dioxide on the pedestrian pavements next to the main road, on five paved public squares that are framing the main road, and on five elevations of the surrounding buildings in the part of Marijin Dvor, urban core of Sarajevo (Figure 1). Since this urban area partially consists of the buildings that are important part of the cultural heritage, application was proposed on two different ways: painting existing elevations and introducing new modular design element, called "Module X" that would be attached to elevations of buildings that are not part of heritage. Since "Module X" element is modular, it can be applicable on buildings with different style, dimensions and function. Total area of 15 778 m^2 was treated with TiO2. Calculating efficiency of TiO_2 coatings was done in accordance to already conducted studies about cleaning possibilities of different TiO_2 products[6].

Based on the studies by Cristal, 100 m^2 of surface painted with KNOxOUT may remove the NO_x equivalent to that produced by a car driven more than 130 km [10]. Institute for Economic Engineering Zenica published that 77% of the cars in Bosnia and Herzegovina are older than 10 years, which corresponds to Euro 3 engine.

[5]Institute for Economic Engineering, Zenica

[6][9]and Global, U. (2017, January 20). *Cristal ACTiv*™. Retrieved from Cristal ACTiv™

According to a study by Association for Emissions Control by Catalyst, Belgium, average emission of NOx for Euro 3 vehicles is 0.5 g/km [11]. Traffic counter [12] states that in observed urban area of approximately 0,5 km in Marijin Dvor pass 26,600 cars daily, which represents 6,6 kg of NO_x. The amount of NO_x emitter per year in the same area is 2409 kg.

4.1. Elevations

This innovative way of purifying the air is application of TiO_2 to the building facades. The basic principle is to coat the tiles or modules by titanium dioxide that fights the pollution near the dense traffic. Representative example for this is the hospital Manuel Gea Gonzales in Mexico. Double skin facade provides the functional, aesthetical, and healthy conditions improvement. Its modules are coated with TiO_2 and they fight the air pollution while providing the shade at the same time.

For the purpose of this study we have designed a module (Module "X") that could be applied on different exterior surfaces. The size of one module is developed from 1x1 meter grid, and due to extrusion additional surfaces would be covered by TiO_2. Total amount of extruded module covered by TiO_2 coating will be 1.82 m^2 (Figure 2).

''Module X'' (Figure 2) is a decorative architectural module that can effectively reduce air pollution when installed near traffic ways on building facades. Modules would be made from lightweight thermoformed plastic panels coated with TiO_2.

We are proposing the application of it to the southern façade of Marijin Dvor building facing the media wall of SCC shopping mall (Figure 1). Besides the improvement of the current bad condition of the building's façade, additional purifying skin will successfully contrast to the light polluting media wall of the shopping mall.

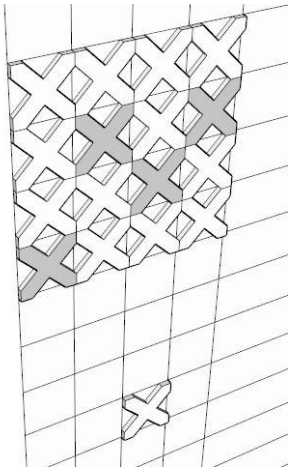


Figure 3. Facade composition using Module 'X'

One module has 1.8 m^2 coated area. The whole façade consist of 704 modules comprising the 1267, 2 m^2 of titanium dioxide coated area. According to the findings by Cristal[7], the leader company in manufacturing titanium dioxide products, TiO_2 coating of 1 m² purifies 80 g per year. Applied to the facade modules, the whole facade would remove 101, 37 kg of NO_x per year out of 2409 kg of NO_x emitted per year, or 4,2%. Further application is done by applying TiO_2 only as a painting, on the several proposed elevations in the same street. Complete surface of hereby proposed elevations is 3375 m^2, which gives the result of 270 kg of NO_x removed from the air out of 2409 kg of NO_x emitted per year, or 11,28%. Total amount of removed NO_x from coatings of TiO_2 on elevations is 371,37 kg per year, or 15,41% of total emitted NO_x per year.

4.2. Pavements:

Further setup implementation was applied on concrete paved pedestrian areas located next to the traffic zone, and were extended to five public squares, with areas ranged from 1000 to 3569 m^2. Two of them are part of exterior design of shopping malls designs and urban integration, another one is located in front of the Church and on the crossroads, while the biggest one is located in front of the Parliament building. Besides squares,

[7]Global, U. (2017, January 20). *Cristal ACTiv™*. Retrieved from Cristal ACTiv™.

TiO_2 coatings were applied on pedestrian ways in this part of the urban core. Total area with concrete pavement is 11 136 m^2. If we continue the same principle that 1 m^2 of TiO_2 removes 80 g of NO_x per year, coating this area will decrease NO_x for 890,88 kg per year, out of 2409 kg of emitted NO_x per year, or 36,98%.

5. Discussion

Total amount of emitted NO_x per year in observed urban area of Marijin Dvor is 2409 kg. Total amount of NO_x removed by specific application on elevations and paved areas after TiO_2 treatment area is showed in charts below:

1. Facades: 371,37kg per year or 15,41%

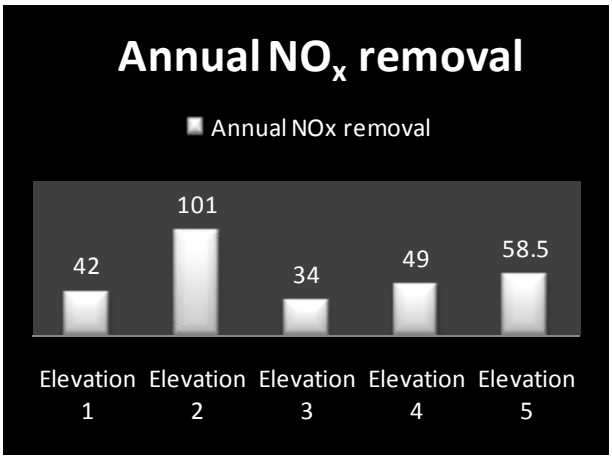


Chart 1. Annual NO_x removal per elevation (In kilograms)

2. Pavements: 890, 88 kg per year or 36,98%

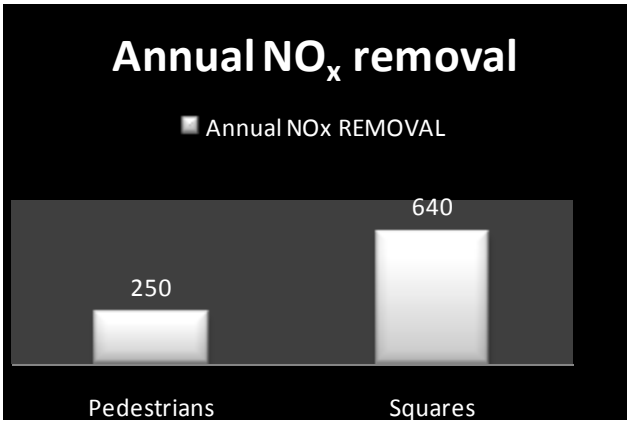


Chart 2. Annual NO_x removal from squares and pedestrian surfaces (In kilograms)

Proposed solution for reducing air pollution by applying innovative approach of TiO_2 coatings would remove annual NO_x emitted from the cars by 1262, 24 kg per year, or 52,39%.

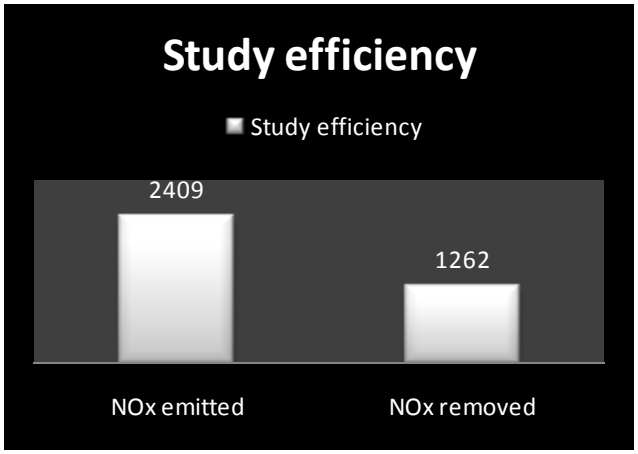


Chart 3. Annual NO_x emission and removal (In kilograms)

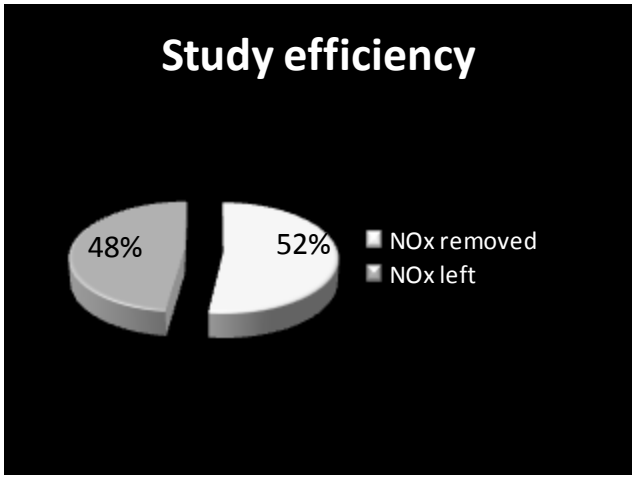


Chart 4. Annual NO_x removal by proposed setup (In percent)

Regarding the fact that this study proposed treatment of only five elevations facing main road with total area covered by TiO_2 of 4642 m^2 and paved areas of 11 136 m^2, results show that it removed more than half NO_x emitted annually by cars that pass in this area. According to the percentage gained from the calculations we can state that application of TiO_2 proved as effective.

Since the most TiO_2 coverage area was applied on pavements, accordingly it gave the best results in NO_x removal. Negative side of application of TiO_2 on pavements is implying that this method raises questions on resistance of these coatings to the weathering and loads, but it is expected that problem can be solved since there are on-going researches regarding improvement of this issue.

5.1. Cost

Total area that would be coated by this research is 15 778 m^2. Brian Pickett, business director for performance chemicals business at Cristal Global, says the paint may cost twice the normal price [10]. Average price for 1 kg of ordinary façade acrylic paint is 2 EUR[8]. According to this, the cost of 1 kg would be 4 EUR. 1 kg of paint can cover 5 m^2 in two coats[6]. This implies around 3000 kg of paint for the setup of this study, and led us to the cost of 12.000 EUR for TiO_2 coating to be applied by this study (excluding labor cost). But the labor cost is one to be predicted and calculated. If the price of painter work per 1 m^2 is 1 EUR in Sarajevo that implies 15 778 EUR for the whole job to be done.

Total cost for applying TiO_2 coating for this study would be 27.778 EUR that is 54.328 KM.

According to the amount of removed NO_x proven by this study we may say that the cost of applying TiO_2 coating is acceptable.

Maintenance

[8]http://www.jub.ba/sites/www.jub.si/files/documents-ba/jub_cenik_2014_bos-www.pdf

Since TiO_2 does not get consumed in the process of photocatalysis, theoretically it can be used indefinitely. This technology is simple to implement, and the only maintenance required is regular water cleaning during the dry season to resume good performance. However, applying coatings of it on the pavement, and elevation walls suggests that layers of TiO_2 can get damaged and it can affect their effectiveness. The main threads to the effectiveness of coating are those concerning pavements because people are walking directly over the coated area. This can affect lower durability because of traces of soles, dirt and gluing the chewing gums for example. Nowadays, studies are being conducted in the best possible method to apply TiO_2 coatings in which they will resist all possible causes of damaging it, including weathering, loads, or any other physical way of harm. There is a hope that this physical harm on TiO_2 coatings along the pavements will be solved.
Studies show that durability of in concrete coatings range between 6-11 months, and between 10-16 months in asphalt coatings [13].
This implies annual recoating of TiO_2.

6. Conclusion

While cities are in a constant process of expanding, parallel increase in the amount of pollution and degrading of natural environment are occurring. Furthermore, increased amount of pollution leaves negative consequences on human's health. Nowadays, companies all over the world are trying to develop innovative sustainable approaches with a goal to remove dangerous compounds from the air, and decrease pollution. Study conducted in this research paper examines a possibility of application and implementation of air improving techniques regarding removal of NO_x from the cars, using titanium dioxide coatings in the case study of Marijin Dvor in Sarajevo. Application was suggested in the parts of the urban core of the city, which contains different possibilities in the methods of coating. Study was conducted in outdoor settings, and suggest significant removal of NO_x. Total amount of emitted NO_x in this area is 2409 kg per year, and innovative approach of TiO_2 coatings in this study removed NO_x by 52, 39%. According to the percentage of removed NO_x together with acceptable cost of the TiO_2 paint, we can state that approach suggested in this study is very effective. Since these studies are innovative and novelty in the world, this conducted research can improve complete understanding on this topic. Furthermore, this study can serve as a basis for further analysis regarding case study of Sarajevo.

7. Bibliography

[1] Davis, D., Divya, C., "Reduction of Air Pollution From Vehicles Using Titanium Dioxide," *International Research Journal of Engineering and Technology (IRJET),* pp. 1308-1314, 2015.

[2] D. Leon, "Cities, urbanization and health," *Oxford Academic - International Journal of Epidemiology ,* pp. 4-8, 2008.

[3] Bettencourt, L. M. A., Lobo, J., Helbing, D., Kühnert, C., West, G. B., "Growth, innovation, scaling, and the pace of life in cities," *Proceedings of the National Academy of Sciences of the United States of America, vol. 104 no. 17,* pp. 7301-7306, 2007.

[4] Benjamin Durakovic, Muris Torlak, "Experimental and numerical study of a PCM window model as a thermal energy storage unit," *International Journal of Low-Carbon Technologies, Volume 12, Issue 3,* pp. 272-280, 2017.

[5] Benjamin Durakovic, Muris Torlak, "Simulation and experimental validation of phase change material and water used as heat storage medium in window applications," *Journal of Materials and Environmental Sciences, Volume 8, Issue 5,* pp. 1837-1846, 2017.

[6] M. Torlak, Delalić, N., Durakovic, B., and Gavranović, H., "CFD-based Assessment of Thermal Energy Storage in Phase-Change Materials - (PCM)," in *International Energy Technologies Conference Proceedings 2014- ENTECH'2014*, Istanbul, Turkey , 2014.

[7] Fujishima, A., Zhang, X., Chimie, Z. R., "Titanium dioxide photocatalysis: present situation and future approaches," *Comptes Rendus Chimie, Volume 9, Issues 5–6, May–June 2006,* pp. 750-760, 2005.

[8] A. Burton, "Titanium Dioxide Photocleans Polluted Air," *Environmental Health Persepectives, It is, of course, hard to predict exactly how much NOX might actually be removed, given the difficulty of controlling city environments in outdoor trials. Vol. 120 (6),* 2012.

[9] H. Akbari, "Evaluation of Titanium Dioxide as a Catalyst for Removing Air Pollutants," PIER Energy-Related Environmental Research, Sacramento, California , 2007.

[10] U. Global, "Cristal ACTiv™," 20 January 2017. [Online].

[11] May, J., Favre, C. and Bosteels, D., "Emissions from Euro 3 to Euro 6 light-duty vehicles equipped with a range of emissions control technologies," Association for Emissions Control by Catalyst, Belgium, 2012.

[12] NTSI, "Traffic Counting on existing primary urban and regional road network under the jurisdiction of the Directorate for traffic in Canton Sarajevo in 2015," NTSI-INSTITUT d.o.o. Sarajevo, Sarajevo, 2015.

[13] D. Osborne, "Durability Quantification of TiO2TiO2 Surface Coating on Concrete and Asphalt Pavements," Journal of Materials in Civil Engineering, 2014.

[14] Hashimoto, K., Irie, H., Fujishima, A. , "TiO2 Photocatalysis: A Historical Overview and," *Japanese Journal of Applied Physics, Vol. 44, No. 12 ,* pp. 8269-8285, 2005.

[15] United Nations, "World Urbanization Prospects: The 2003 Revision," New York: United Nations, 2004.

[16] C. Sarajevo, "Register of Emissions to the Air," Ministry of Spatial Planning and Environmental Protection, Sarajevo, 2012.

[17] W. Wilson, J. Chow, C. Claiborn, W. Fusheng, J. Engelbrecht and J. Watson, Monitoring of particulate matter outdoors, Chemosphere, 2002.

[18] Y. Li, Q. Chen, H. Zhao, L. Wang and R. Tao, Variations in PM10, PM2.5 and PM1.0 in an Urban Area, Atmosphere , 2015.

[19] "World's first smog filtering tower goes on tour," The Guardian, 2016.

[20] M. Utell and M. Frampton, Acute health effects of ambient air pollution: the ultrafine particle, J. Aerosol Med, 2013.

[21] I. f. E. Engineering, Zenica.

[22] H. Dylla, M. M. Hassan, L. N. Mohammad, T. Rupnow and E. Wright, "Evaluation of the Environmental Effectiveness of Titanium Dioxide Photocatalyst Coating for Concrete Pavement," Transportation Research Board 89th Annual Meeting (Publication No. 10- 0963), Washington, D.C., 2010.

[23] S. S. Amaral, J. A. d. Carvalho, Jr. and M. A. M. Costa, "An Overview of Particulate Matter Measurement Instruments," *Atmosphere 2015,* p. 3, 2015.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 136~144
Available online at: http://pen.ius.edu.ba

Comparative Life Cycle Costing Analysis of Green Roofs: The Regional Aspect

Serdar Ulubeyli[1], Volkan Arslan[1], Aynur Kazaz[2]
[1]Department of Civil Engineering,Bulent Ecevit University
[2]Department of Civil Engineering, Akdeniz University

Article Info

Article history:

ReceivedMay 16th, 2017
Revised June14th, 2017
Accepted June17th, 2017

Keyword:

Benefits of green roofs
Extensive green roofs
Intensive gree roofs
Life cycle assessment
Life cycle costing

ABSTRACT

The increasing environmental concerns and poor practices force construction industry to take some remedial measures for green and sustainable built environment. Especially in urban areas, one of these measures is to build green roofs for minimizing the environmental pollution. In fact, green roofs present a number of economic, environmental, and social benefits. However, compared with traditional roofs, green roof investments have high capital and maintenance costs and this makes potential investors hesitant about their applications. Therefore, in the present study, benefits and life cycle costing parameters of green roofs were evaluated through a literature review. In this context, numerical inputs and findings of past studies were utilized. In doing this, a special emphasis was placed on the regional characteristic of such investments as it is a natural feature of any life cycle costing analysis. In conclusion, the majority of benefits and life cycle costing parameters was found to be highly variable, and thus, any life cycle costing assessment that will be performed in the future should be case-sensitive instead of using some generalized or raw data. Therefore, based on findings and results of this study, industrial practitioners and potential customers may have a useful source of economic, environmental, and social information about green roofs while researchers may be encouraged for more region-specific studies.

Corresponding Author:

Serdar Ulubeyli,
Department of Civil Engineering,
Bulent Ecevit University,
Incivez Mahallesi, Farabi Kampusu, 67100, Zonguldak, Turkey
Email: ulubeyli@beun.edu.tr

1. Introduction

The sustainable built environment phenomena can be defined as providing both healthy environment for people through improving the quality of life and a livable future for current and next generations in terms of social, economic, and environmental conditions [1]. The construction industry, one of the leading industries in developed and developing countries, has an important role to improve social, economic, and environmental conditions of the sustainable built environment. However, it is responsible for high values of energy and resource consumption, solid waste production, and greenhouse gas emission [2, 3]. These adverse effects force the construction industry to take some preventive measures to reduce its environmental damage to a minimum level. Today, green roofs are chosen both as a technological device that has potential to decrease energy and pollution based environmental problems and as a construction application that can minimize the lack of green fields in urban areas in many countries around the world [4]. This is because they present numerous benefits for societies and individuals, such as savings from energy and storm water [5], fall in the temperature of roof membrane [6], improving air quality [7], rise in habitat and biodiversity [8], mitigation of

urban heat island effect [9], noise reduction and aesthetic view [10], and formation of recreation areas [11]. However, due to high initial and maintenance costs, they have not attracted the required attention of clients so far in many countries. For example, in some regions in Germany and Japan, green roof applications are mandatory [12]. As another instance, the Korean government subsidizes 50% of the initial investment cost of green roofs implemented in major cities [13]. Thus, in order to encourage investors for green roofs in practice, it seems to be necessary to present their economic advantages in the long term through the analysis of their lifecycle costs besides environmental benefits.

Therefore, the aim of this study was to provide a useful source of financial information about green roofs for industrial practitioners and to encourage researchers for more region-specific studies as life cycle costing naturally needs and demands a regional resolution [14]. For this purpose, past studies concerning life cycle costing of green roofs in the literature were comparatively analyzed. In this context, a number of indicators such as unit construction cost, lifespan, life cycle costing method, interest rate, and economic, environmental, and social benefits were presented given their regional aspects.

2. Materials and Methods

In the literature, there are a few dozens of studies that compare green roofs applied in different geographical regions. However, it was seen that, in these studies, only two or three different cities were compared with each other [15-17]. It means that the literature seems to lack a comparative life cycle costing study emphasizing the regional aspect of green roofs as a whole. Therefore, in the present study, this type of past researches was divided into two sub-categories as extensive (Table 1) and intensive (Table 2) green roofs by reviewing the related literature and was compared in terms of unit construction cost, life span, life cycle costing method, and interest rate in a regional manner. Moreover, in order to compare and reveal the potential regional variability of benefits, they were individually investigated from the economic, environmental, and social point of view.

Table 1.Life cycle costing studies on extensive green roofs

Authors	Country	Unit Cost ($/m^2)	Method(s)	Lifespan (year)	Discount rate (%)
Porsche and Köhler [15]	Germany-USA-Brazil	85-90	NPV	90	n.a.
Zhang et al. [16]	Germany-Singapore	31.72	NPV	40	5
Clark et al. [4]	USA	232	NPV	40	5
Carter and Keeler [5]	USA	158.82	NPV	40	4
Blackhurst et al. [9]	USA	97.04	BCR	30	5
Niu et al. [18]	USA	306	NPV	40	6-7
Wu and Smith [19]	USA	107.64	PBP-NPV-BEP	40	2.8
Bianchini and Hewage [20]	USA	130-165	NPV-PBP	40-55	2-8
Mullen et al. [21]	USA	158-306	NPV	40	n.a.
Sproul et al. [22]	USA	172	NPV	50	3
Joksimovic and Alam [23]	Canada	236.45	NPV	50	5
Peri et al. [24]	Italy	75.05	NPV	40	6
Angelakoglou et al. [25]	Greece	90-180	PBP	25	n.a.
Claus and Rousseau [12]	Belgium	141.9	NPV	50	4
Tsang and Jim [26]	Hong Kong	150	NPV	40	5
Chan and Chow [27]	Hong Kong	68	NPV-PBP	25	4.25
Peng and Jim [28]	Hong Kong	64	BCR-PBP	40	4.25
Lee et al. [29]	South Korea	134.5	n.a.	2-100	n.a.
Shin and Kim [30]	South Korea	23.32	BCR	20	5.5
Liu and Hong [31]	China	241.2	BCR	40	5
Wong et al. [32]	Singapore	89.86	NPV-SIR-AIRR-PBP-DPBP	40	6.15

Table 1 includes extensive green roof researches that were analyzed in this study.Among them, Porsche and Köhler [15] compared green roofs in Germany, USA, and Brazil while Zhang et al. [16] examined green roofs in Germany and Singapore. The remaining ones can be categorized into three geographical locations as the American region (USA and Canada), the European region (Italy, Greece, and Belgium), and the Asian region (Hong Kong, South Korea, China, and Singapore).

Table 1 includes extensive green roof researches that were analyzed in this study. Among them, Porsche and Köhler [15] compared green roofs in Germany, USA, and Brazil while Zhang et al. [16] examined green roofs in Germany and Singapore. The remaining ones can be categorized into three geographical locations as the American region (USA and Canada), the European region (Italy, Greece, and Belgium), and the Asian region (Hong Kong, South Korea, China, and Singapore).

Compared with extensive green roofs, there are much less previous studies regarding intensive ones (Table 2). This may be because intensive green roofs have higher initial investment and maintenance costs and it would likely be a vain attempt to investigate their viabilities unless the feasibility of extensive green roofs is revealed. Although Porsche and Köhler [15] performed the single study about intensive green roofs in the European region, their research takes into account three different regions together. In other words, it neither focuses on nor presents a comparative perspective of the European region. Similarly, Chui et al. [17] compared intensive green roofs in Hong Kong and USA. Therefore, intensive green roof studies analyzed were categorized into two geographical locations as the American region (USA) and the Asian region (Hong Kong, Singapore, and Australia).

Table 2. Life cycle costing studies on intensive green roofs

Authors	Country	Unit Cost ($/m2)	Method(s) used	Lifetime (year)	Discount rate (%)
Porsche and Köhler [15]	Germany-USA-Brazil	340-380	NPV	90	n.a.
Chui et al. [17]	Hong Kong-USA	153-273	NPV	30	n.a.
Bianchini and Hewage [20]	USA	165-540	NPV-PBP	40-55	2-8
Liu et al. [33]	USA	168.34	NPV	20	4.5
Langston [34]	Australia	n.a.	BEP	25-100	3
Peng and Jim [28]	Hong Kong	256	BCR-PBP	40	4.25
Wong et al. [32]	Singapore	178.93-197.16	NPV-SIR-AIRR-PBP-DPBP	40	5.15

3. Results and Discussion

In this section, life cycle costs of green roofs was comparatively evaluated from a regional perspective to present the difference of the effect of costs and benefits. In the literature, the data used in life cycle costing studies can be grouped as primary and secondary data. Primary data represents the data provided directly from the manufacturer or market while secondary data is derived from the existing literature [35]. For the sake of reliability, primary data is preferred more to compile. In past studies about green roofs, unit construction costs and interest rates were usually used as primary data while lifespan and benefits were taken as secondary data. Here, monetary values of data were included using local values needed for the relevant region.

3.1. Life cycle costing parameters

Considering previous studies, it seems that there are three causes behind the green roof choice of clients. First, roof gardens in the USA are fashionable due to the positive effect of a better aesthetic view on the renting or selling price of a flat or an office since there is no legal regulation on rental rates as in Germany [15]. Similarly, in Brazil, people prefer roof flats with green terraces for a beautiful garden view and for an open green space required in tropical climates. Second, from the viewpoint of storm water management, energy and cost savings increase through the green infrastructure used in Germany instead of traditional rain water

harvesting system in Singapore [16]. Third, cost-efficiency of green roof investments are more in the USA than Hong Kong because of higher land prices in Hong Kong [17].

Given unit construction costs of extensive roofs, they vary in a very large interval between $97-306 for the American region, $75-180 for the European region, and $23-241 for the Asian region. Interestingly, the difference between the lowest and highest values in the same region can be more than ten times. Such an enormous difference is valid even in the same country such as USA, Hong Kong, and South Korea. However, taking the lowest values as a baseline, the most inexpensive extensive roofs are in Asia while the most expensive ones are in America, which shows a difference of more than four times. As an expected finding, unit construction costs of intensive roofs are at least two times higher than those of extensive roofs and similarly vary in a very large interval between $165-540 for the American region and $178-256 for the Asian region. Although the difference between the lowest and highest values in the same region or country is not very high, it can be more than three times, denoting a serious difference. However, the lowest values of American and Asian regions are very similar. Main factors affecting the unit construction cost can be listed as the quality of materials and the cost of labor. As a result, it seems impossible to standardize unit construction costs of green roofs in any region or country, and thus, it is a necessity for investors to assess current market prices of construction materials to be used and regional labor costs.

As can be seen in Tables 1 and 2, life cycle costing methods used in past studies are net present value (NPV), benefit-cost ratio (BCR), payback period (PBP), breakeven point (BEP), savings to investment ratio (SIR), adjusted internal rate of return (AIRR), and discounted payback period (DPBP). Among them, NPV is the most frequently used method. However, three methods (i.e., SIR, AIRR, and DPBP) were used in one research only. In conclusion, life cycle costing methods used in different regions of the world seem not to change.

In terms of lifespan of green roofs, there is no common attitude in past studies. This is also valid for comparisons between extensive and intensive roofs and between geographical regions. However, as lifespan was taken 40 years in most of these studies, it seems to be reasonable to accept the average lifespan of any kind of green roofs as 40-50 years which is equal to the lifespan of an ordinary reinforced concrete building [36].

Among all life cycle costing parameters, interest rate is likely the most uncertain input and its variation can lead to an overestimation or underestimation of the total cost [37]. Considering previous studies, it is evident that neither extensive and intensive roofs nor geographical regions have specific interest rates. These values change in a relatively small interval between 2-8%. In fact, almost all of past researches were carried out in developed economies. Accordingly, this low and stagnant level of the presented interest rates may turn to high and unstable rates in undeveloped economies, indicating a warning signal for potential green roof investors while making their decisions on the roof type.

3.2. Benefits of green roofs

Benefits of green roofs may be divided into three main categories such as economic, environmental, and social, as given in Table 3. Economic benefits are energy saving, longer roof life, increased property value, and other cost savings. Environmental benefits include storm water management, improved air quality, mitigation of urban heat island effect, and increased biodiversity. Social benefits contain fire protection, green space, thermal insulation, noise insulation, and aesthetic view [30]. In fact, these three categories cannot be assessed individually because economic benefits may also provide environmental and/or social benefits and vice versa. For example, energy saving contributes to less energy production and thereby to reduction in greenhouse gas and CO2 emissions, leading to richer biodiversity and healthier living conditions. In other words, types of benefits should not be perceived as totally independent factors, but as integrated and engaged advantages.

Table 3. Benefits of green roofs

Author(s)	Economic Benefits					Environmental Benefits					Social Benefits				
	Energy saving	Longer roof life	Increased property value	Other cost savings	Storm water management	Air quality	Urban heat island	Biodiversity	Fire protection	Green space	Thermal insulation	Noise reduction	Aesthetic view
Porsche and Köhler [15]			X		X					X	X		
Wong et al. [31]	X	X											
Clark et al. [4]	X				X	X							
Carter and Keeler [5]	X	X			X	X	X			X			
Blackhurst et al. [9]	X				X		X			X			
Niu et al. [18]	X				X	X							
Lee et al. [29]					X								
Tsang and Jim [26]	X				X					X			
Wu and Smith [19]	X	X			X	X							
Bianchini and Hewage [20]	X	X	X	X	X	X	X	X		X			X
Claus and Rousseau [12]	X	X	X	X	X	X	X	X	X			X	X
Liu and Hong [31]	X	X		X									
Angelakoglou et al. [25]	X												
Chan and Chow [27]	X												
Mullen et al. [21]	X				X	X							
Joksimovic and Alam [23]					X								
Sproul et al. [22]	X	X			X	X	X						
Langston [34]	X	X			X	X			X	X	X		X
Liu et al. [33]					X	X							
Peng and Jim [28]						X	X			X			
Shin and Kim [30]	X			X	X	X	X						
Zhang et al. [16]	X				X								
Chui et al. [17]	X				X								X

3.2.1. Economic benefits

A building's energy use for heating and cooling is an important component of its sustainable design [5]. Green roofs have potential to decrease the energy consumption of a building. Energy savings associated with the increased insulation depend on the size of a building, the climate zone, and the type of roof [12]. The amount of energy savings is expected to be between 40-110% in Hong Kong, compared to other roofs [27], 1.5% in Belgium [12], and 3.3% in the USA [5]. In this regard, electricity prices per kWh are $0.185 in Hong Kong [27], $0.140 in Belgium [12], and $0.069 in the USA [19]. As a result, both saving amount and its monetary value seem not to change regionally. However, the monetary value is clearly prone to much higher values in many countries, presenting a larger room and motivation for such a saving.

Protection of green roof membranes through the reduction in surface temperature by multiple layers results in a two or three times longer roof life [5, 10, 12, 18, 20, 22, 31, 32, 34]. In this context, as the effect of sunlight on the roof life will show totally different characteristics from a region to another, it needs to be investigated by future studies.

Green roofs may contribute to increase the market value of properties via aesthetics. The increase rate varies between 2-5% [20] in property values and reaches up to 25% in hiring prices [15]. From the regional point of view, both land cost and property value will likely rise in highly urbanized regions subject to dense population and suffering from the lack of green areas.

Lastly, there are some policies applied by governments to encourage investors for the use of green roofs. In New York, one-time tax reduction of $48/m2 is allowed [20]. Similarly, the Flemish government in Belgium stimulates municipalities to grant subsidies of at least $36.16/m2 [12]. Hence, these kinds of direct cost savings seem to be a mission of regional administrations in increasing green areas.

3.2.2. Environmental benefits

The most cited type of environmental benefits is storm water management. Green roofs reduce storm sewer pipe size, water utility fee [5], costs of upgrading storm water infrastructure [22], and storm water tax rate [12]. While storm water fees in some cities of Germany have been reduced for buildings with green roof, investors in Switzerland take 20% of the cost of their investment back through storm water management [38]. In the USA, building owners could annually save between $0.08/m2 [4] and $0.38/m2 [20] by reducing storm water runoff amount. In South Korea, annual storm water runoff decreases 14.7-25.6% [30]. All these findings reveal the significance of storm water management practices and policies that can be applied and adjusted according to regional precipitation amounts.

Green roofs are also expected to have positive effects on air quality improvement [4, 19]. The corresponding monetary value is calculated considering mitigation or prevention of air pollutants and thereby reduction of taxes and other legal payments. The monetary value of mitigation of NOX in the USA was calculated $1.07/m2 by Clark et al. [4] and Mullen et al. [21], $0.03/m2 by Bianchini and Hewage [20], and $0.011/m2 by Sproul et al. [22]. It is $0.43/m2 in Belgium [12] and $0.085/m2 in Hong Kong. In terms of SO2 and CO2, the monetary value of their prevention was taken $0.013/m2 and 5.7 kg/m2, respectively. From a general perspective, the mitigation of all air pollutants will provide a $60 benefit per year [19]. Since the amount of these polluting compounds can take totally different values in different regions and environmental policies (i.e., sanctions and incentives) can change with region, more regional researches seem to be necessary for a better life cycle analysis.

Urban heat island (UHI) increases energy consumption, concentration of harmful pollutants, emissions of CO2 to the atmosphere, and affects health conditions [39]. Green roofs reduce the UHI effect by providing a medium for evapotranspiration and altering the surface albedo [9]. However, some authors [5, 31, 32] define this benefit as speculative while others tend to include it in life cycle costing analysis [9, 12, 20, 22]. In conclusion, as the amount of the UHI mitigation will vary between regions owing to their urbanization levels and climate conditions, green roof investments should be supported by governments given their environmental advantages regardless of financial revenues.

Biodiversity is described as the variety of living organisms, ecological complexes in which they occur, and ways in which they interact with each other and the physical environment [40]. There is no doubt that green roofs have potential to enhance biodiversity although this benefit is not represented in the life cycle costing analysis due to unavailability or unreliability of data [12, 20]. In addition, it is very difficult to evaluate regional effects of the increased biodiversity. Consequently, similar to the UHI effect, the increased biodiversity could be used as a qualitative motivator.

3.2.3. Social benefits

Interestingly, these five benefits are also expected to provide indirect economic advantages to investors through the increased value and the marketable potential of property [15]. First, thermal and sound insulation potentials of green roofs may decrease or eliminate extra costs of insulation works in the construction phase and energy expenditures in the operating stage. On the one hand, it is difficult to calculate the thermal insulation effect because it depends on climate, the water content of layers, the water flow in the drainage layer, and the wind velocity [15]. On the other hand, the annual energy saving amount through the thermal insulation for extensive green roofs was calculated 57.6 kWh/m2 [28]. In terms of sound insulation, the annual monetary equivalent of this effect was accepted approximately $0.34/m2 [12]. Second, sedums in a roof are water retaining plants and might decrease the risk of fire. However, as this risk in one particular reinforced concrete building is extremely small, the fire protection feature of green roofs is neglected in life cycle costing analysis [12]. Third, the increased green recreation area especially by intensive roofs could improve the quality of life of residents [26]. It is a fact that green roofs do not provide positive social effects as much as parks do [20], but the reduction of stress and illnesses and an improved productivity [41]. Overall, regional differences seem to have a significant impact on all social benefits. Fire protection and thermal insulation is directly related with climate while green space, noise reduction, and aesthetic view is affected by the urbanization level. All of these arguments denote a regional aspect. As it seems difficult to obtain reliable input data, social benefits can constitute the qualitative aspect supporting the investment decision of potential building owners.

4. Conclusions

As initial investment and maintenance costs of a green roof can be much higher than those of a conventional wooden or flat roof, many clients may be reluctant to invest in such a roof. This study is an attempt to reveal the findings of past researches about cost parameters and benefits of green roof investments in their life cycles. In doing this, an emphasis was naturally placed on the regional characteristic of such investments, which is a must to be taken into account in any life cycle costing analysis.

Generally speaking, there are three causes of the green roof choice of clients and they have financial drivers as an expected outcome. Looking at unit construction costs, they cannot be standardized and may have high variability. Therefore, current market prices of construction materials to be used and regional labor costs should be assessed in a detailed manner. Similarly, some economic factors (i.e., land cost, property value, and the effect of sunlight on the roof life) and all environmental benefits/policies (i.e., storm water management practices, the amount of the polluting compounds in the air and the related environmental regulations, the amount of the UHI mitigation, and the increased biodiversity) seem to be highly sensitive to regional characteristics and need for an in-depth investigation. This is also valid for all social benefits (i.e., fire protection, thermal insulation, green space, noise reduction, and aesthetic view). However, although these benefits can interestingly bring indirect financial gains via the increased value and the marketable potential of property, they can encourage the investment decision of potential clients qualitatively since it is difficult to compile reliable and concrete input data. On the contrary, life cycle costing methods do not change with region and NPV seems to be the most common approach in this regard. In this computation, the average lifespan of any kind of green roofs can be accepted 40-50 years. However, despite the fact that interest rates used up to date are low and stagnant, these rates may have a role to adversely affect the decision of potential green roof investors especially in undeveloped regions. Similarly, although energy saving amount and its monetary value do not have a regional effect, the monetary value may tend to rise in current global financial conditions and this may motivate potential customers more. In this context, governments may provide an additional motivation through tax reduction and/or subsidies to increase green areas.

Consequently, given the aforementioned results, it is seen that most of benefits and life cycle costing parameters are open to variation as the literature suggests and that life cycle costing evaluation of green roofs can be described case-sensitive. In other words, industrial professionals and potential green roof customers should consider parameters and benefits specific to that case and then calculate the economic viability of their particular investments. Keeping all these issues in mind, this study may enable industrial practitioners and potential clients to have a useful source of economic, environmental, and social information about green roofs and researchers to encourage for more region-specific studies.

Acknowledgements

The authors gratefully acknowledge financial supports provided by Committees on Research Grants of Bulent Ecevit University and Akdeniz University.

References

[1] O. Ortiz, F. Castells, and G. Sonnemann, "Sustainability in the construction industry: a review of recent developments based on LCA," *Construction and Building Materials*, vol. 23, pp. 28-39, 2009.

[2] L. Melchert, "The Dutch sustainable building policy: a model for developing countries?," *Building and Environment*, vol. 42, pp. 893-901, 2005.

[3] M. Zimmermann, H. J. Althaus, and A. Haas, "Benchmarks for sustainable construction: a contribution to develop a standard," *Energy and Buildings*, vol. 37, pp. 1147-1157, 2005.

[4] C. Clark, P. Adriaens, and F. B. Talbot, "Green roof valuation: a probabilistic economic analysis of environmental benefits," *Environmental Science and Technology*, vol. 42, pp. 2155-2161, 2008.

[5] T. Carter and A. Keeler, "Life-cycle cost-benefit analysis of extensive vegetated roof systems," *Journal of Environmental Management*, vol. 87, pp. 350-363, 2008.

[6] R. Kumar and S. C. Kausik, "Performance evaluation of green roof and shading for thermal protection of buildings," *Building and Environment*, vol. 40, pp. 1505-1511, 2005.

[7] T. L. Carter and L. Fowler, "Establishing green roof infrastructure through environmental policy instruments," *Environmental Management*, vol. 42, pp. 151-164, 2008.

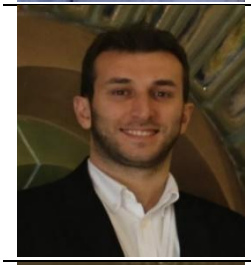
[8] T. L. Carter and T. C. Rasmussen, "Hydrologic behaviour of vegetated roofs," *Journal of the American Water Resources Association*, vol. 42, pp. 1261-1274, 2007.

[9] M. Blackhurst, C. Hendrickson, and H. S. Matthews, "Cost-effectiveness of green roofs," *Journal of Architectural Engineering*, vol. 16, pp. 136-143, 2010.
[10] S. W. Peck, C. Callaghan, M. E. Kuhn, and B. Grass, "Greenbacks from green roofs: forging a new industry in Canada," Peck & Associates, Status Report prepared for Canada Mortgage and Housing Corporation, 1999.
[11] E. Oberndorfer, J. Lundholm, B. Bass, R. R. Coffman, H. Doshi, N. Dunnett, S. Gaffin, M. Köhler, K. K. Y. Liu, and B. Rowe, "Green roofs as urban ecosystems: ecological structures, functions, and services," *BioScience*, vol. 57, pp. 823-833, 2007.
[12] K. Claus and S. Rousseau, "Public versus private incentives to invest in green roofs: a cost benefit analysis for Flanders," *Urban Forestry and Urban Greening*, vol. 11, pp. 417-425, 2012.
[13] T. Hong, J. Kim, and C. Koo, "LCC and LCCO2 analysis of green roofs in elementary schools with energy saving measures," *Energy and Buildings*, vol. 45, pp. 229-239, 2012.
[14] W. Kloepffer, "Life cycle sustainability assessment of products," *International Journal of Life Cycle Assessmen*t, vol. 13, pp. 89-95, 2008.
[15] U. Porche and M. Köhler, "Life cycle costs of green roofs: a comparison of Germany, USA, and Brazil," in *Proceedings of World Climate & Energy Event*, 2003, pp. 461-467.
[16] D. Zhang, R. M. Gersberg, W. J. Ng, and S. K. Tan, "Conventional and decentralized urban stormwater management: A comparison through case studies of Singapore and Berlin, Germany," *Urban Water Journal*, vol. 9006, pp. 1-12, 2015.
[17] T. F. M. Chui, X. Liu, and W. Zhan, "Assessing cost-effectiveness of specific LID practice designs in response to large storm events," *Journal of Hydrology*, vol. 533, pp. 353-364, 2016.
[18] H. Niu, C. Clark, J. Zhou, and P. Adriaens, "Scaling of economic benefits from green roof implementation in Washington, DC," *Environmental Science and Technology*, vol. 44, pp. 4302-4308, 2010.
[19] T. Wu and R. E. Smith, "Economic benefits for green roofs: a case study of the skaggs pharmacy building, university of Utah," *International Journal of Design and Nature and Ecodynamics*, vol. 6, pp. 122-138, 2011.
[20] F. Bianchini and K. Hewage, "Probabilistic social cost-benefit analysis for green roofs: a lifecycle approach," *Building and Environment*, vol. 58, pp. 152-162, 2012.
[21] D. Mullen, M. Lamsal, and G. Colson, "Green roof adoption in Atlanta, Georgia: the effects of building characteristics and subsidies on net private, public, and social benefits," *Environmental Science and Technology*, vol. 47, pp. 10824-10831, 2013.
[22] J. Sproul, M. P. Wan, B. H. Mandel, and A. H. Rosenfeld, "Economic comparison of white, green, and black flat roofs in the United States," *Energy and Buildings*, vol. 71, pp. 20-27, 2014.
[23] D. Joksimovic and Z. Alam, "Cost efficiency of Low Impact Development (LID) stormwater management practices," *Procedia Engineering*, vol .89, pp. 734-741, 2014.
[24] G. Peri, M. Traverso, M. Finkbeiner, and G. Rizzo, "The cost of green roofs disposal in a life cycle perspective: Covering the gap," *Energy*, vol. 48, pp. 406-414, 2012.
[25] K. Angelakoglou, M. Dimitriou, and G. Gaidajis, "Comparative evaluation of flat roof thermal systems in Greece," *International Journal of Sustainable Building Technology and Urban Development*, vol. 4, pp. 243-257, 2013.
[26] S. W. Tsang and C. Y. Jim, "Game-theory approach for resident coalitions to allocate green-roof benefits," *Environment and Planning A*, vol. 43, pp. 363-377, 2011.
[27] A. L. S. Chan and T. T. Chow, "Energy and economic performance of green roof system under future climatic conditions in Hong Kong," *Energy and Buildings*, vol. 64, pp. 182-198, 2013.
[28] L. L. H. Peng and C. Y. Jim, "Economic evaluation of green-roof environmental benefits in the context of climate change: The case of Hong Kong," *Urban Forestry & Urban Greening*, vol. 14, pp. 554-561, 2015.
[29] K. Lee, H. Kim, G. Pak, S. Jang, L. Kim, C. Yoo, Z. Yun, and J. Yoon, "Cost-effectiveness analysis of stormwater best management practices (BMPs) in urban watersheds," *Desalination and Water Treatment*, vol. 19, pp. 92-96, 2010.
[30] E. Shin and H. Kim, "Analyzing green roof effects in an urban environment : a case of Bangbae-Dong, Seoul," *Journal of Asian Architecture and Building Engineering*, vol. May, pp. 315-322, 2015.
[31] L. P. Liu and G. X. Hong, "Popularizing path research on green roof project in China rural region: cost-effectiveness assessment," in *Proceedings of World Automation Congress (WAC)*, 2012.

[32] N. H. Wong, S. F. Tay, R. Wong, C. L. Ong, and A. Sia, "Life cycle cost analysis of roof top gardens in Singapore," *Building and Environment*, vol. 38, pp. 499-509, 2003.
[33] Y. Liu, V. F. Bralts, and B. A. Engel, "Evaluating the effectiveness of management practices on hydrology and water quality at watershed scale with a rainfall-runoff model," *Science of the Total Environment*, vol. 511, pp. 298-308, 2015.
[34] C. Langston, "Green roof evaluation: a holistic "long life, loose fit, low energy" approach," *Construction Economics and Building*, vol. 15, pp. 76-94, 2015.
[35] L. Belussi and B. Barozzi, "Mitigation measures to contain the environmental impact of urban areas: a bibliographic review moving from the life cycle approach," *Environmental Monitoring and Assessment*, vol. 187, pp. 745-158, 2015.
[36] P. Ricci, F. De Luca, and G. M. Verderame, "6th April 2009 L'Aquila earthquake, Italy: reinforced concrete building performance," *Bulletin of Earthquake Engineering*, vol. 9, pp. 285-305, 2011.
[37] A. Ferreira and J. Santos, "Life-cycle cost analysis system for pavement management at project level: sensitivity analysis to the discount rate," *Internal Journal of Pavement Engineering*, vol. 14, pp. 655-673, 2013.
[38] U. Berardi, A. GhaffarianHoseini, and A. GhaffarianHoseini, "State-of-the-art analysis of the environmental benefits of green roofs," *Applied Energy*, vol. 115, pp. 411-428, 2014.
[39] M. Santamouris and D. Kolokotsa, *Urban Climate MitigationTechniques*, UK: Routledge, 2016.
[40] C. R. Groves, D. B. Jensen, L. L. Valutis, K. H. Redford, M. L. Shaffer, J. M. Scott, J. V. Baumgartner, J. V. Higgins, M. W. Beck, and M. G. Anderson, "Planning for biodiversity conservation: putting conservation science into practice," *BioScience*, 52, pp. 499-512, 2002.
[41] D. B. Rowe, "Green roofs as a means of pollution abatement," *Environmental Pollution*, vol. 159, pp. 2100-2110, 2011.

BIBLIOGRAPHY OF AUTHORS

Serdar Ulubeyli is an Associate Professor in the Department of Civil Engineering at Bulent Ecevit University, Turkey. His areas of academic research interests include green buildings, green roofs, and sustainable built environment. He has published many papers in various scientific journals and proceedings.



Volkan ARSLAN is a PhD student and aResearch Assistant in the Department of Civil Engineering at Bulent Ecevit University, Turkey. His areas of academic research interests include green buildings, green roofs, and sustainable built environment. He has published many papers in various scientific journals and proceedings.

Aynur KAZAZ is a Professor in the Department of Civil Engineering at Akdeniz University, Turkey. Her areas of academic research interests include green buildings, green roofs, and sustainable built environment. She has published many papers in various scientific journals and proceedings.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 145~151
Available online at: http://pen.ius.edu.ba

Use of Structural Equation Modeling in Ecotourism: A Model Proposal

Yaşar Selman Gültekin[1], Pınar Gültekin[2], Osman Uzun[2], Hande Gök[2]
[1]Departement of Forest Economics, Faculty of Forest,Düzce University
[2]Departement of Landscape Architecture, Faculty of Forest, Düzce University

Article Info

Article history:

Received May 23rd, 2017
Revised June14th, 2017
Accepted June16th, 2017

Keyword:

Structural equation modeling,
Analyze methodology,
Ecotourism,
Stakeholder analysis,
Landscape planning

ABSTRACT

Structural Equation Modeling (SEM) is an effective model improves and test technique which is explain the relationships between variables in mixed hypotheses related to statistical models and provide to test theoretical models as whole. SEM is an analyze technique that combined the multivariate statistical methods which has been used especially to analyze models in social sciences studies, psychology, sociology, education, economics and marketing.
The aim of this study, to provide for researchers introducing the use of structural equation modeling in ecotourism and to explain model specifications in stakeholder analysis. There are given some definitions, evaluations of model fits, model structures, examples from the ecotourism and landscape planning using SEM and ecotourism model proposals from literature related to SEM methodology. In the conclusion section it will be given a model proposal and recommendations using SEM in ecotourism and stakeholder analysis.

Corresponding Author:

Yaşar Selman Gültekin,
Departement of Forest Economics, Faculty of Forestry,
Düzce University,
Orman Fakültesi, Konuralp Yerleşkesi, 81620, Merkez / DÜZCE.
Email: selmangultekin@duzce.edu.tr

1. Introduction

Ecotourism is a type of tourism that includes visits to natural areas and special purposes such as landscaping, wildlife, wilderness exploration, observation and living, leaving as little impact on the environment as possible [1]. With the increase of people's education levels and environmental consciousness, travels especially in natural and culturally sensitive areas have been developing rapidly in recent years. These changes in the structure of international tourism demand increase the demand for ecotourism travels [2].
While participating in the activities of ecotourism, they witness the plants and other living things on the one hand, and on the other hand they have the opportunity to establish friendships with local people and to learn about their cultures and traditional life styles. The people of the region protect ecotourism as an inheritance of their natural richness while raising their economic levels with alternative incomes and job opportunities. In an ecotourism-focused planning process, ensuring more effective involvement of stakeholders in ecotourism activities is challenging as an effective resource management [3].
Interest in modeling structural equilibrium for model analysis is increasingly increasing in studies carried out in the field of social sciences. Structural Equation Modeling (SEM) is a method of analysis consisting of a combination of statistical methods that are used in many areas such as psychology, sociology, education, economics and marketing. Structural equilibrium modeling is an effective model testing and development

technique that can explain the cause-and-effect relationship of variables in mixed hypotheses related to statistical models and allows the theoretical models to be tested as a whole.
The aim of this study is to conduct stakeholder analysis in participatory ecotourism planning, to identify stakeholders' perceptions of ecotourism and their attitudes, and to discuss the feasibility of structural equation modeling as a new approach to the solution of existing problems. The method of "Structural Equation Modeling (SEM)" which is an unused method in ecotourism planning in Turkey will be applied in participatory ecotourism planning and will have an important place in the future to fill the gap in the literature and studies on ecotourism.

1.1. Ecotourism

The phenomenon of ecotourism has emerged with the recognition of the potential benefit of people as a result of their curiosity towards nature [4].According to reference [5], the concept of ecotourism is a concept that comes to the agenda with the concept of sustainability. Ecotourism, which is the basis of conservation of ecological balance, has emerged as a result of sustainable development [6]. Ecotourism is a broader issue than the activities of tourists who are nature and environmentally conscious. Ecotourism is the whole of environmental, economic and social relations [7].
According to [8], ecotourism is based on ecological sustainability approaching environmental and cultural values with a conservative and sensitive approach. According to [9], ecotourism is more than just tourism activity in natural areas. But the lack of a widely accepted definition of ecotourism and the lack of a common definition of features and dimensions that distinguish ecotourism from other types of tourism is the biggest shortcoming in this area [6]. In this respect, ecotourism is a type of tourism that has been described differently by different circles because of its different forms [10]. According to [11], ecotourism is a type of tourism that takes its natural history, including its local cultures. Ecotourists are those who visit natural areas without consuming natural resources and strive to protect this area [6]. According to [12], ecotourism is an educational journey to nature that contributes to the protection of the ecosystem and respects the existence of local people [6]. [13], has introduced a different perspective to ecotourism by identifying ecotourism as recreational activities related to the natural history or natural life of an area such as bird watching, wildlife observation, whale watching, nature photography, plant survey which do not consume natural resources.
The World Tourism Organization (WTO) and the United Nations (UN) Commission for Sustainable Development declared 2002 the "International Year of Ecotourism" and commissioned the WTO on this subject. The World Ecotourism Summit, held in Quebec, Canada, in May 2002, with the participation of 1,100 delegates from 133 countries, attempted to identify a common definition adopted by all countries. Accordingly, ecotourism has been adopted as "an approach or attitude that protects the social and cultural integrity of the earth while assisting the economic development of the local people, securing the sustainability of the natural resources of the earth" [1]. According to this definition, the most important feature distinguishing ecotourism from other activities based on nature is the ecological sustainability and the aim of acquiring experiences based on education and learning [14].
The concept of ecotourism is concerned with the fact that the actual travel is helping to protect and develop the areas visited. Because ecotourism has a wide variety of elements, it is necessary to understand its structure first [2].In order to ensure long-term sustainability of ecotourism, it is necessary to take into consideration the basic elements of the structure of this tourism route (Figure 1).
The work and thought partnership of local people, decision-makers, private sector, NGO's and scientists, indispensable stakeholders of ecotourism planning, is a process that can be applied and facilitated.

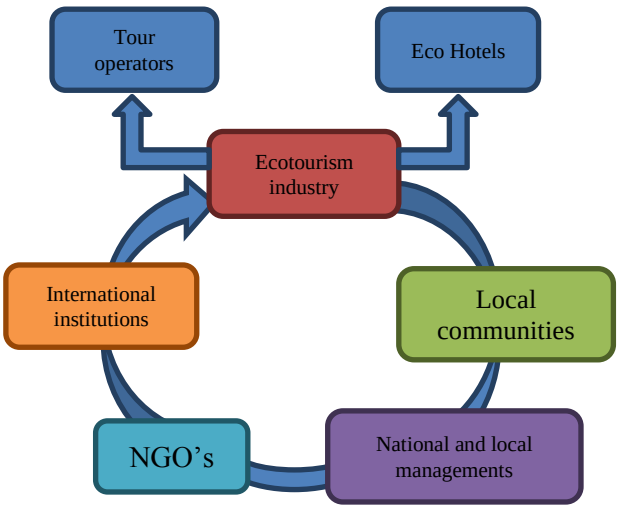


Figure 1. Basic elements of ecotourism [2]

1.2. Structural Equation Modelling

Structural Equation Modeling (SEM) is a method of analyzing the use of many fields such as psychology, sociology, education, economics and marketing in recent years and it is composed of multivariate statistical methods [15][16]. It is possible to come across many studies using SEM in the field of tourism abroad [17] [18] [19] [20]. It can be said that the use of SEM is very limited in the field of ecotourism planning, with many studies made in different branches of science in our country by using SEM [21] [15] [22] [23]. For this reason, it is possible to say that SEM is being used as a new method in the field of ecotourism in our country. SEM is basically based on the researcher's thoughts about a research topic by testing a model of inter-variable relationships that existed before the research is done with the help of the data obtained in the research result. The most significant difference between methods such as variance analysis (ANOVA), multivariate analysis of variance (MANOVA), factor analysis (FA), regression analysis, which are the most used statistical methods in SEM researches [22]. The main objective of the SEM is to explain the interdependency relationship pattern between the one or more observed variables and the implicit non-observable sets of structures[15] [24].

It is stated that the three main components of the structural equation models (SEM) are historical development [24]. These components are path analysis, conceptual synthesis of structural models and measurement models, and finally general estimation processes. Historical development of SEM should be addressed through some statistical concepts on a historical level. These analyzes are regression analysis, path analysis, confirmatory factor analysis (CFA) and finally SEM [26] [23].

The concept of confirmatory factor analysis (CFA) emerged in the 1950s. Karl Jöreskog developed the DFA in 1960 with his theoretical studies of whether or not the data set of a defined structure could be tested [25]. FA is used to construct measurement instruments whereas CFA is used to test the existence of theoretical structures[23].

SEM is mainly a general statistical methodology [27]. SEM uses road diagrams to show default models for causal relationships. Structural equation modeling was first recognized as "JKW" models because it was developed by Karl Jöreskog, Keesling and Wiley. It was later used as "Linear Structural Equation Models" with the development of the LISREL (Linear Structural Relations) program [28].[29] states that it would be better to call it "Factor Analytical Structural Equation Models" because SEM is based on FA. However, only the SEM concept has been used in recent years due to the use of nonlinear structural equality models [26][23].

The most general form is a structural equation model, the measurement model and the structural model are two parts. The measurement model specifies how the hidden variables or theoretical structures are related to the observed variables and how they are represented. The structural model identifies the causal relationships between hidden variables and describes causal effects [21] (Figure 2).

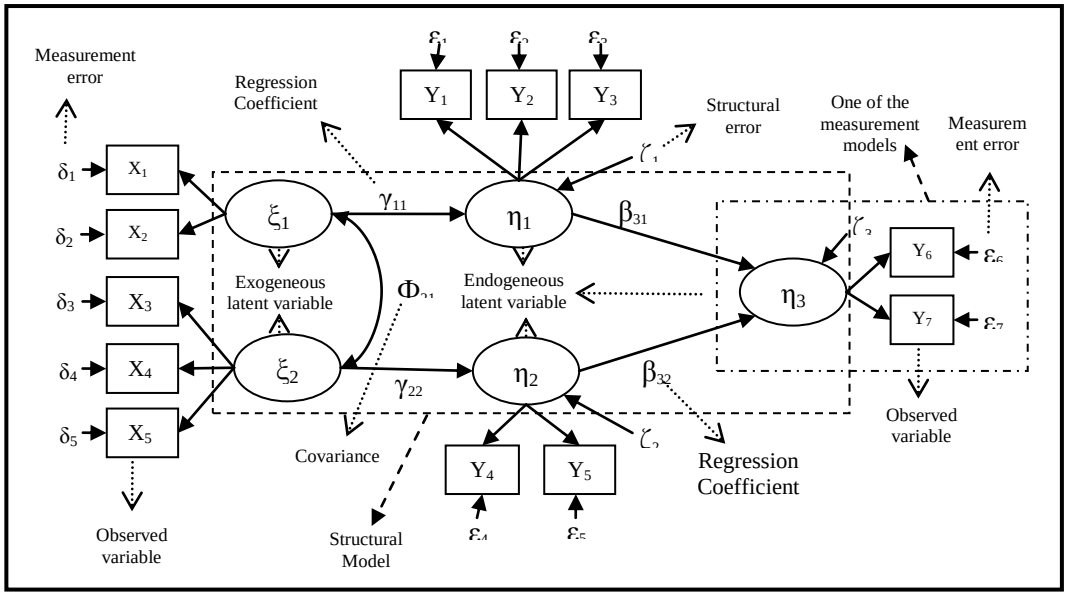


Figure 2. Structural Equation model [30] [22]

When the model is tested in SEM, many different criteria are used in evaluating the conformity of the created model. These measures are called goodness of fit indexes. There are a number of statistical functions that this goodness of fit index has. Similarity ratios between chi-square statistics (χ2), Root-Mean-Square Error Approximation (RMSEA), Goodness-of-Fit Index (GFI) and Adjusted Goodness-of-Fit Index [28].
Other fit measures of SEM include Parsimony Normed Fit Index (PFI), Parsimany Goondness of Fit Index (CFI), Comparative Fit Index (CFI), Incremental Fit Index (IFI), Relative Fit Index (RFI)[31]. Researchers using LISREL often use GFI, AGFI, RMSEA, CFI, and NNFI criteria as well as chi-square values in their studies [21][32]. In the AMOS analysis, the AIK (Akaike Information Criterion), CAIC (Consistent Akaike Information Criterion) and ECVI (Expected Cross Validation Index) model comparison indexes are used in addition to these criteria [33]. Table 1 summarizes the most commonly used metrics for evaluating the suitability of the SEM and the data for these metrics.

Tablo 1. Evaluation of SEM's Suitability[15] [31] [33].

Fit Indexes	Good fit	Acceptable fit
General Model Fit		
χ^2	$0 \leq \chi^2 \leq 2sd$	$2sd \leq \chi^2 \leq 3\ sd$
(χ^2/sd)	$0 \leq \chi^2/sd \leq 3$	$3 \leq \chi^2/sd \leq 4\text{-}5$
Comparative Fit Indexes		
NFI	≥0,95	0,94-0,90
NNFI	≥0,95	0,94-0,90
IFI	≥0,95	0,94-0,90
CFI	≥0,97	≥0,95
RMSEA	≤0,05	0,06-0,08
Absolute Fit Indexes		
GFI	≥0,90	0,89-0,85
AGFI	≥0,90	0,89-0,85
Conservative Fit Indexes		
PNFI	≥0,95	-
PGFI	≥0,95	-
Root Mean Based Fit Indexes		
RMR	≤0,05	0,06-0,08
Model Comparison Fit Indexes		
AIC	Smaller values than the compared model	
CAIC	Smaller values than the compared model	
ECVI	Smaller values than the compared model	

2. Materials and Methods

The data obtained by scanning the work material on ecotourism and SEM studies are the theoretical models that can be used in tourism and ecotourism studies. SEM methodology is used in analyzing the views, thoughts, perceptions, attitudes and perspectives of the interest groups. SEM can be used as an analysis tool in

this regard, given that the views of many interest groups need to be analyzed in ecotourism planning. SEM is used in some studies on tourism and ecotourism activities [34][35] [36] [37] [38] [39] [40] [41][42]. From this point, it is possible to transform the factors obtained from studies related to ecotourism through SEM into a theoretical model.

3. Results and Discussuion

When we look at the work done in the field of ecotourism in Turkey, it is seen that interest groups' perception about perception attitudes takes place [43] [44]. Factors that are effective in the ecotourism perception are the variables regarding the obstacles in front of ecotourism activities, attractiveness of ecotourism resources, resource development and management strategies.

In order to analyze the stakeholders of ecotourism planning by using SEM, the ecotourism perception (EP) model which is theoretically developed, the obstacle in front of the application of ecotourism activities (OFAE), the degree of attraction of ecotourism resources (DAER), resource development (RD) and management strategies (MS). According to this, studies related to the subject can be examined and the Ecotourism Perception Measurement Model (Research Model) can be created as in Figure 3.

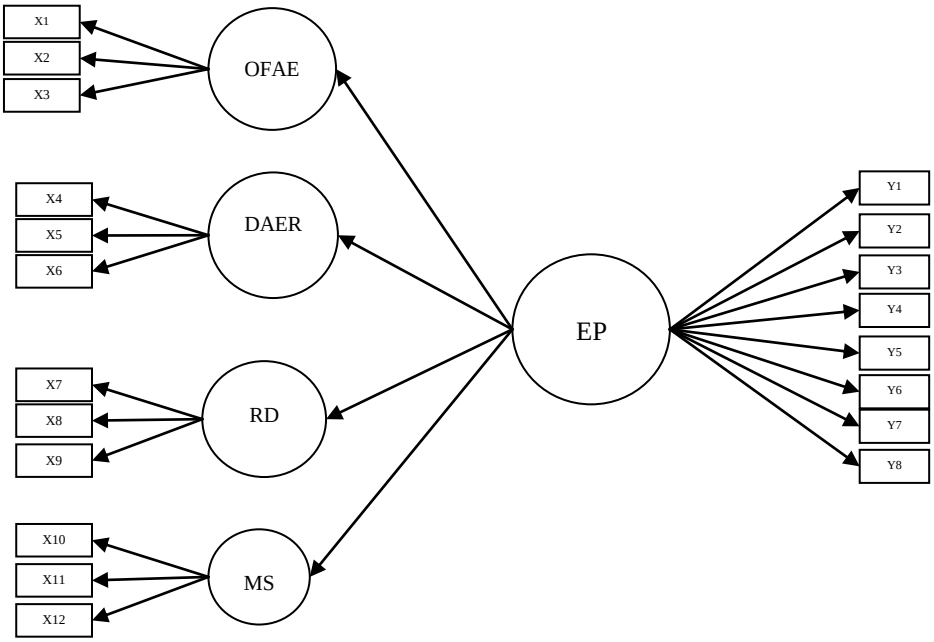


Figure 3. Theoretical research model of ecotourism perception

4. Conclusion

It is seen that SEM is limited (10-20%) when it is used in the world literature from studies done in the field of social sciences [22]. This rate is much lower in our country. In recent years, SEM has been used in scientific fields such as statistics, economics, business, marketing, psychology, sociology in national articles and reports [21]. Since the use of SEM in ecotourism is very limited in Turkey, the use of SEM in solving socio-economic problems and the continuing increase in such studies can provide significant contributions to the use of SEM in ecotourism and especially in solving socio-economic problems [45].

With participatory ecotourism planning using SEM methodology, it will be possible to conduct scientific studies to develop the local people in place and to sustain the development by evaluating local potential. It will also be possible to obtain guidance on how the ecotourism sector should develop with different stakeholders in different land use policies and how it is likely to develop in future years.

It is possible to use SEM as a method for solving problems related to ecotourism management. However, in the works to be done about SEM, the establishment of measurement and structural models requires a theoretical and statistical infrastructure. If this precondition is met, healthy results will be obtained from the work to be done.

Acknowledgment

This study was supported by BAP-2015.02.01.307numbered Scientific Research Project of Duzce University.

References

[1]. Koçan N., "Mudurnu (Bolu) ve yakın çevresi peyzaj özelliklerinin ekoturizm kapsamında irdelenmesi", *Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü DergisiGÜFBED/GUSTIJ*, 1 (1), 67-78,-2011.

[2]. Demir C. ve Çevirgen A., "Ekoturizm Yönetimi (1. Basım)", Ankara: Nobel Yayın Dağıtım, 2006.

[3]. Yeni, E., Gürleyen Kuru, F.,Gülnar, Ö, Örmeci, S., Özerhan, Y., "Zonguldak Natural Tourism Development Plan", Ministry of Forestry and Water Affair, Directorate of Protection of Nature and National Parks. 10 th. Region Sinop, 2013.

[4]. Kılıç N., "Bolu-Göynük ve yakın çevresi doğal ve kültürel kaynaklarının ekoturizm açısından değerlendirilmesi", *Doktora Tezi*, A.Ü. Fen Bilimleri Enstitüsü, Ankara, 2006.

[5]. Türker N., Çetinkaya A., "Batı Karadeniz bölümü ekoturizm potansiyeli", Detay Yayıncılık, 2009.

[6]. Gültekin P., "Düzce Uğursuyu ve Aksu Havzaları ekoturizm potansiyelinin belirlenmesi ve peyzaj yönetimi", *Yüksek Lisans Tezi*, Düzce Üniversitesi Fen Bilimleri Enstitüsü, Düzce, 2010.

[7]. Ahipaşaoğlu S., Çeltek E., "Kırsal Turizm", Gazi Kitabevi, Ankara, 2006.

[8]. Beeton S., "Ecotourism: A Practical Guide for Rural Communities", Land links Press, Australia, 1998.

[9]. Ross, S., Wall, G., "Ecotourism: Towards Congruence Between Theory And Practice",*Tourism Management*,20 (1), 123-132, 1999.

[10].Steele, P., "Ecotourism: an economic analysis",*Journal of Sustainable Tourism*, 3(1), 29-44,1995.

[11].Ziffer K., "Ecotourism: The Uneasy Alliance", Conservation international, Ernst and Young, Washington DC., 1989.

[12].Wight, P., A. "Ecotourism: Ethics or Eco-Sell?", *Journal of Travel Research*, 31 (3): 3-9,1993.

[13].Hvenegaad G., "Ecotourism: A Status Report and Conceptual Framework", *The Journal of Tourism Studies*, 5,2, 24-35,1994.

[14].Rodger K., Moore S A., Newsome D., "Wildlife Tours in Australia: Characteristics, The Place of Science and Sustainable Tourism", 15 (2), 160-178,2007.

[15].Yılmaz, V., Çelik, H.E., "Bankacılık Sektöründe Müşteri Memnuniyeti ve Bankaya Bağlılık Arasındaki İlişkinin Yapısal Eşitlik Modelleriyle Araştırılması",*VII. Ulusal Ekonometri ve İstatistik Sempozyumu*, 26-27 Mayıs 2005, İstanbul.

[16].Yılmaz, V., Çelik, H. E., "Lirsel ile Yapısal Eşitlik Modellemesi – I", Pegem Akademi, s.186, 2009.

[17].Malaeb, Z.A., "Using Structural Equation Modeling to Investigate Relationships Among Ecological Variables", *Environmental and Ecological Statistics*, Vol. 7, pp. 93-111,2000.

[18].Parkins, J.R., Stedman, R.C. , Beckley, T.M., "Forest sector dependence and community well- being: A structural equation model for new Brunswick and British Columbia", *Rural Sociology*, 1549-0831, 2003, 68 (4) 554-572.

[19]. Grace, J.B., "Structural Equation Modelling and Natural Systems", ISBN: 9780521837422, Cambridge University Press, New York, 2006.

[20].Jonsson, M., Wardle, D., "Structural Equation Modelling Reveals Plant community Drivers of Carbon Storage in Boreal Forest Ecosystems", *Biology Letters*, Royal Society Publishing, Vol. 6, pp. 116-119, 2010.

[21].Yılmaz, V., "LISREL ile Yapısal Eşitlik Modelleri: Tüketici Şikâyetlerine Uygulanması", *Anadolu Üniversitesi Sosyal Bilimler Dergisi*,cilt: 4, no.1, ss.77-90,2004.

[22].Ayyıldız , H., Cengiz, E., "Pazarlama Modellerinin Testinde Kullanılabilecek Yapısal Eşitlik Modeli (YEM) Üzerine Kavramsal Bir İnceleme",*Süleyman Demirel Üniversitesi, İktisadi ve İdari Bilimler Fakültesi*, Y. 2006, C. 11, S.1, s. 63-84.

[23].Akıncı Deniz, E., "Yapısal Eşitlik Modellerinde Bilgi Kriterleri", Mimar Sinan Güzel Sanatlar Üniversitesi, Fen Bilimleri Enstitüsü, İstatistik Anabilim Dalı, *Yayınlanmamış Doktora Tezi*, İstanbul, 2007.

[24].Hoyle, R.H., "Handbook of structural equation modeling", The Guilford Press, United States of America, 2012.

[25].Bollen, K.A., "Structural equations with latent variables", John Wiley & Sons, USA, 1989.

[26].Schumacker, R.E., Lomax, R.G., "A Beginner's Guide to Structural Equation Modeling", Second Edition, Mahwah, NJ: Lawrence Erlbaum Associates, 2004, 498 p.

[27]. Kline, R.B., "Principles and practices of structural equation modeling", The Guilford Press, New York, USA, 2011.

[28].Jöreskog, K. Sörbom, D.," LISREL 8: User's Reference Guide", Scientific Software International Inc., 2001.

[29].Bentler, P.M., "EQS 6 structural equations program manual", Multivariate Software Inc., Encino, CA, 2006.

[30].Rigdon, E., "The Form of Structural Equation Models", Last updated: April 11, 1996, http://www.gsu.edu/~mkteer/sem2.html, (Access date: 07.02.2012), 1996.

[31].Şimşek, Ö. F., "Yapısal Eşitlik Modellemesine Giriş (Temel İlkeler ve LISREL Uygulamaları)", ISBN: 9944-495-07-7, s. 224, Ekinoks, Ankara, 2007.

[32].Hu, L.T. , Bentler, P.M., "Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives", *Structural Equation Modeling-a Multidisciplinary Journal*, 1070-5511, 10.1080/10705519909540118, 1999, 6 (1) 1-55.

[33].Meydan, C. H., Şeşen, H., "Yapısal Eşitlik Modellemesi (AMOS Uygulamaları)", ISBN: 978-605-5437-01-5, Detay Yayıncılık, Ankara, 2011.

[34].Untachai, S., "Modeling Residents' Perceptions on Ecotourism in Upper Northeast, Thailand", In Kerpitak, C., Heuer, and K., Benabdelhafid (Eds.), *International Journal of Business Tourism Applied Sciences* (pp. 6-19). Bangkok, Suan Dusit Rajabhat University, 2015.

[35]. Ko, D., Stewart, W. P., "A structural equation model of residents' attitudes for tourism developments", *Tourism Management*, (23): 521–530, 2002.

[36].Gursoy, D., Jurowski, C., Uysal, M., "Resident Attitudes A Structural Modeling Approach", *Annals of Tourism Research*, 2002, Vol. 29, No. 1, pp. 79–105.

[37]. Meng, F., "An Examination of Destination Competitiveness from the Tourists' Perspective: The Relationship between Quality of Tourism Experience and Perceived Destination Competitiveness", *Doctoral Thesis*, Faculty of the Virginia Polytechnic Institute and State University, 224 p., Virginia, 2006.

[38]. Lee, T. H., "An ecotourism behavioral model of national forest recreation areas in Taiwan", *International Forestry Review*, 2007, Vol. 9, (3): 771-785.

[39]. Chaitip, P., Chaiboonsri, C., Kovács, S., Balogh, P., "A Structural Equation Model: Greece's Tourism Demand for Tourist Destination", *Applied Studies in Agribusiness and Commerce*, 2008.

[40].Li, C., "Modeling Forest Recreation Visitors: A Multi-Cultural Marketing Perspective", Paper presented at Conference on Sustainable Forest Management and Carbon Sequestration in Taiwan and Japan. Huisun Forest Station, Experimental Forest Administration, National Chung Hsing University, Taiwan, 2007.

[41].Zhang, H., Lei, S. L., "A structural model of residents' intention to participate in ecotourism: The case of a wetland community", *Tourism Management*, 2012, (33): 916-925.

[42].Ven, S.,"Host Residents' Attitude toward Community-based Ecotourism: Empirical Study in Southwestern Cambodia", *Journal of Tourism & Hospitality*, 2015, (4): 1, 2015.

[43].Gültekin, P., Gültekin, Y.S., Uzun, O., "Düzce Uğursuyu ve Aksu Havzalarında Katılımcı Ekoturizm Algı Ölçeğinin Geliştirilmesi", *Peyzaj Mimarlığı V. Kongresi*, 14-17 Kasım 2013, 904-921, Adana.

[44].Gültekin, P., Gültekin, Y.S., Uzun, O., "Katılımcı Planlamada Yerel Halk Ekoturizm İlişkisi: Düzce Aydınpınar Köyü Örneği", *III. Uluslararası Odundışı Orman Ürünleri Sempozyumu*, 658-671, Kahramanmaraş, 2014.

[45].Kayacan, B., Gültekin, Y.S., "Use of Structural Equation Modeling in Solving Socioeconomic Problems in Forestry", *III. Ormancılıkta Sosyo-ekonomik Sorunlar Kongresi*, İstanbul, 2012.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June2017, pp. 152~160
Available online at:http://pen.ius.edu.ba

Operational Stability and Degradation of Organic Solar Cells

Efe Çetin YILMAZ[1], Muhammet Kaan YEŞİLYURT[2], İlhan Volkan ÖNER[2], Gökhan ÖMEROĞLU[3], Ahmet Numan ÖZAKIN[3]
[1]Ataturk University Pasinler Vocational School, Department of Electronics and Automation
[2]Ataturk University Pasinler Vocational School, Department of Electricity and Energy
[3]Ataturk University Engineering Faculty, Department of Mechanical Engineering

Article Info

Article history:

ReceivedMay25th, 2017
Revised June14th, 2017
Accepted June16th, 207

Keyword:

Degradation
Efficiency of organic solar cells,
Stability,
Life-cycle of OSCs

ABSTRACT

Recently, Organic solar cells (OSC) have been increasingly utilized all over the world. The changes made in the organic components of the organic solar cells enable them to exhibit good features such as mechanical flexibility, lightness and high power generation efficiency even under lower light intensities. However, operational stability is an important parameter for organic solar cells. Despite the aforementioned advantages of organic solar cells, degradation in operational environments limits their use in harsh conditions. Studies have shown that the organic layer and the cathode layer of the OSCs are degraded by external factors, and this adversely affects the operational stability and productivity of OSCs considerably. The overall efficiency of an organic solar cell is defined as a function of life cycle and efficiency of energy generation. Therefore, the shorter the life cycle becomes, the lesser the overall efficiency of OSCs gets. Recent studies are focused on improving the operational stability and power generation efficiencies of OSCs by reducing the effects degradation induced by external factors, such as climatic conditions and thermal fatigue. The purpose of this study is to assess how organic solar cells work, how they degrade from external factors, such as water and water vapor, and how these parameters affect the operational stability as well as the efficiency of the organic solar cells.

Corresponding Author:

İlhan Volkan ÖNER,
Pasinler Vocational School, Department of Electricity and Energy Ataturk University 25200 Erzurum, Turkey
Email: ivoner@atauni.edu.tr

1. Introduction

This study is part of our researches and studies on renewable energy systems in identifying the problems in their utilization and seeking solutions to them. In this study we tackle the stability and degradation mechanisms of organic solar cells. Organic solar cells are very promising for their superior characteristics such as mechanical flexibility, lightness and high power generation efficiency even under lower light intensities.

Recently, Organic solar cells (OSC) have been increasingly utilized all over the world. The changes made in the organic components of the organic solar cells enable them to exhibit good features such as mechanical flexibility, lightness and high power generation efficiency even under lower light intensities. However, operational stability is an important parameter for organic solar cells. Despite the aforementioned advantages of organic solar cells, degradation in operational environments limits their use in harsh conditions. Studies have shown that the organic layer and the cathode layer of the OSCs are degraded by external factors, and this adversely affects the operational stability and productivity of OSCs considerably[1].

The overall efficiency of an organic solar cell is defined as a function of life cycle and efficiency of energy generation, which is mostly referred to as Power Conversion Efficiency (PCE). Therefore, the shorter the life cycle becomes, the lesser the overall efficiency of OSCs gets. Recent studies are focused on improving the operational stability and power generation efficiencies of OSCs by reducing the effects of degradation induced by external factors, such as climatic conditions and thermal fatigue[1].
The main objective in solar cell researches is, for sure, to bring in solar systems having high power conversion efficiency. With the introduction of fullerene electron acceptors and other new approaches, organic solar cells have improved efficiencies remarkably in the last decade[1, 2]. On the other hand, the absorption band of OSC within the solar spectrum is now broader than ever[3]. The total yield from a solar cell is calculated by its efficiency multiplied by its lifetime. Therefore, not alone he high efficiency, but also the longer lifetime is important. And no doubt, in order for the lifetime to be longer, stability and degradation resistivity are important parameters that also affect their value (yield over cost) as current energy production is largely limited by the low durability.[1]In the recent years, by means of the changes made in the internal structure of the solar cells and thanks to the newly introduced synthetic materials, noteworthy improvements have been achieved in terms of operational stability of organic solar cells[1].
In recent years, numerous internal structures have been developed that can be less affected by degradation factors. In addition, improvements have been made to the operating stability and lifetime of OSCs operating under constant light intensity[4]. In modern OSCs manufactured with an aluminum-titanium top cathode layer, operational stability and efficiency is improved[1]. With this improvement, degradation rate of OSCs in air environment has been slowed down.
The purpose of this study is to assess how organic solar cells work, how they degrade from external factors, such as water and water vapor, and how these parameters affect the operational stability as well as the efficiency of the organic solar cells. State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

2. Material and methods (Working Principle of Organic Solar Cells)

Organic solar cells (OSCs) are considered to be a green solar energy technology. OSCs are attractive mainly because they can be fabricated from various organic compounds with modifiable structures and exhibit excellent flexibility, high power conversion efficiency (PCE) under low light irradiation, and promising see-through power-generation windows. Over the course of the past few years, various aspects of organic solar cells have been extensively studied, including synthesis and application of new materials, modeling of physical processes, large-scale manufacturing, stability improvement, et cetera [5].
A single-junction OSC comprises five or six layers stacked on the surface of a supporting substrate, which is normally a piece of glass or transparent plastic. These five or six layers are as illustrated in Fig. 1.

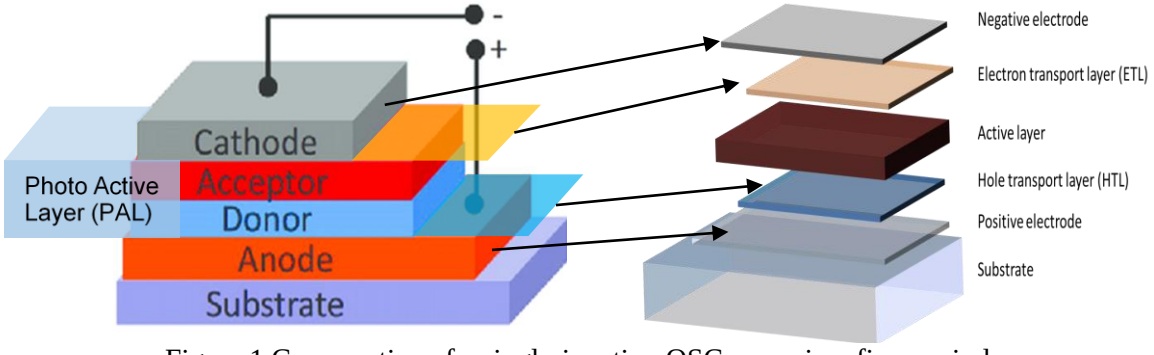


Figure 1.Comparative of a single-junction OSC comprises five or six layers

An OSC consists of:

- A transparent conductive electrode (Cathode, normally of indium-tin-oxide, mostly referred to as ITO),
- Cathode buffer layer (CBL) (also known as electron-transport layer (ETL)),
- one or two photoactive layers (PALs) composed of an electron donor and an electron acceptor,
- Anode buffer layer (ABL) (also known as hole-transport layer (HTL)),
- a top metal electrode (Anode, generally aluminum or silver),
- and a supporting substrate (normally of glass or transparent plastic)

The HTL also functions as an electron-blocking layer, or an exciton-blocking layer. Similarly, the ETL may also function as a hole-blocking layer. For simplicity, buffer layers are denoted as HTL and ETL in figures throughout the manuscript. An extra encapsulation film is sometimes employed. The structure of these layers are shown in Fig. 1 [1].

In Fig. 2 the electricity generation, namely the working principle of an organic solar cell is illustrated.

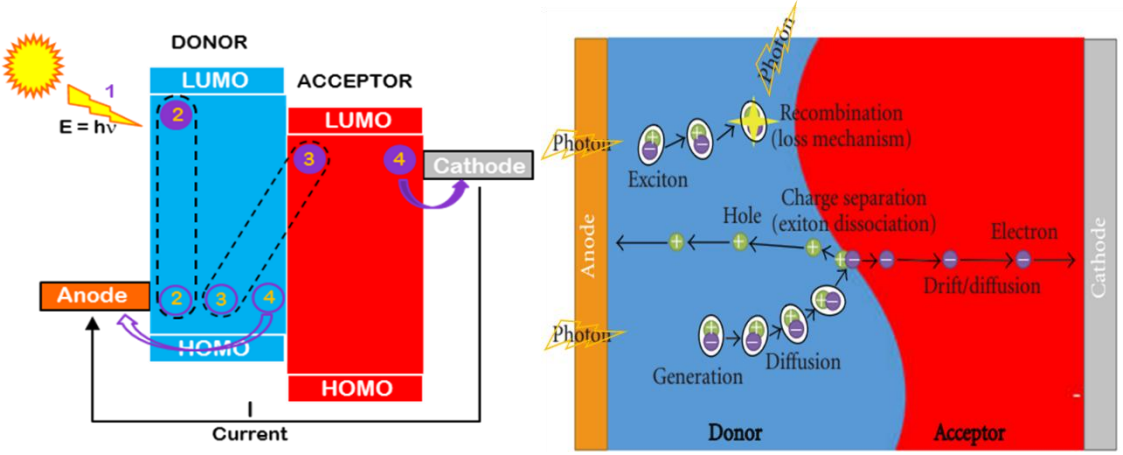


Figure 2.Photocurrent generation mechanism in active layers of an organic solar cell[6]

How photocurrent is being generated in PAL of an OSC:

1) The incident light reaches to OSC

2) An electron is excited by the photon energy (E=hv), and it moves to the higher energy level (LUMO), forming a combination of an electron and an associated hole, an exciton.

3) When an exciton does not reach an interface, it relaxes back into the ground state (loss mechanism) and no current is generated. Therefore, by diffusing to the donor-acceptor interface, the exciton transfers the charge at the interface to the electron acceptor, after which a free electron in the Acceptor and a free hole in the Donor is formed. This mechanism is known as the exciton dissociation.

4) separated charges diffuse to the electrodes, namely the electron reaches the cathode while the hole reaches the anode.

As a result of these four steps, an electric current flows in the opposite direction of the electron flow, namely from cathode to anode.So following challenges should be overcome in order for OSCs to be able to generate photocurrent[1, 7]:

-Photons, which generates tightly-bound excitons instead of free charge pairs, should be absorbed

-Since the diffusion lengths of excitons in organic semiconductors are low, donor-acceptor interface should be advanced and charge transfer be made;

-Recombination of excited charges should be avoided at or before the donor-acceptor interface;

-The cooling of hot charge-transfer excitons at the donor-acceptor interface should be prevented

-The low or imbalanced carrier mobilities in semiconductors should be overcome.

Classification of OSCs are generally made by whether the electron donor (D) and acceptor (A) layers are planar or intermixed, and are named as planar-heterojunction (PHJ) or bulk-heterojunction (BHJ), respectively. Illustrated in Fig. 3 is schematic views of these two different types of organic solar cells. The left hand side is the planar heterojunction organic solar cell, and the right hand side is the bulk heterojunction organic solar cells.

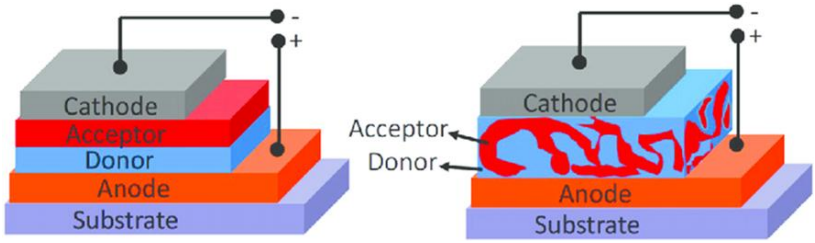


Figure 3. Planar and bulk heterojunction organic solar cells

As you can see here, the acceptor and donor in the active layer are blended and dispersed one in another in bulk systems. So that they can be made thick enough for effective photon absorption without the difficult processing involved in orienting a layered structure while retaining similar level of performances. For the PHJ-OSCs, multiple layers of semiconductors are deposited in sequence.
Looking at the application areas of solar cells, a single diode circuit design with two resistances is defined and Shockley equation is obtained. This circuit is described below, in Fig. 4.

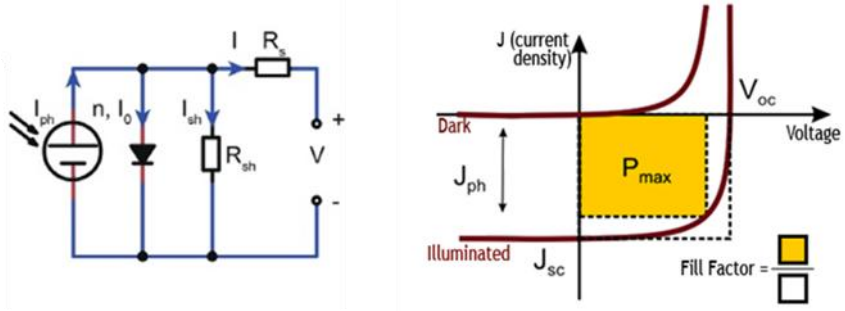


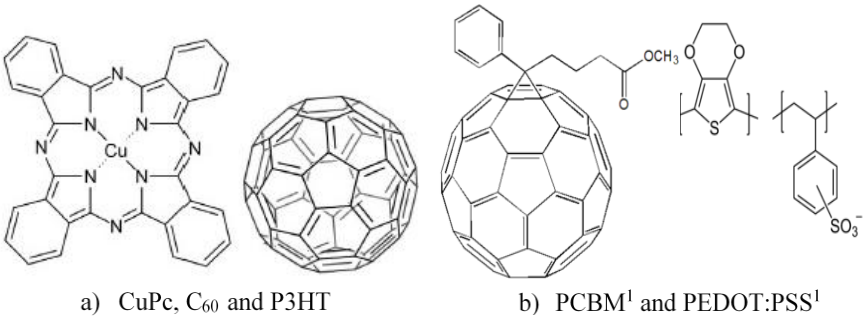
Figure 4. (a: [1]) Single diode solar cell under irradiance(b: [8]I-V curve of a solar cell in dark and under sunlight

$$I - I_0 \times \left[e^{e \times \left(\frac{V - I \times R_S}{n k_B T}\right)} - 1 \right] - \frac{V - I \times R_s}{R_p} + I_{light} = 0 \quad (1)$$

It gives the I–V (current-voltage) characteristic of an idealized diode in either forward or reverse bias (applied voltage)In this equation, I is the diode current, V is the externally applied voltage, I0 is the current at saturation point, T is the temperature, R_s is the serial resistance, R_p is the parallel resistance, k_B is the Boltzmann constant and I light is the light induced electrical current. The R_s in the series refers to the resistance of serial resistance semiconductors and the resistance to noise resistance of the connection electrodes. The R_s value should ideally be zero. If the R_s resistance is too high or R_{sh} has very low values, the solar cell will be damaged.Therefore, these parameters should be calculated using Eq. (1) and from the single diode I-V curve given in Fig. 4[1]. Moreover, the actual I-V curve for OSCs differentiates from the ideal I-V curve[9]Qi and Wang summarized factors influencing the open circuit voltage (V_{oc}) and fill factor (FF) [10, 11]. While open circuit voltage is also a function of a number of things such as temperature, irradiance and material microstructure, it is briefly determined by the difference between the energy levels where the exciton dissociation takes place. Figure 4.(b) shows the I-V curve along with FF, V_{oc} and short circuit current, theoretical max power indications. FF loss is typically indicated by the appearance of the S-shaped I-eV curve, which is caused by the electric field formed by accumulated charges in devices. Scharber et al. suggested that a donor material with a HOMO of 5.4 eV, and a bandgap of 1.4 eV is most suitable for coupling with fullerene to achieve a theoretical PCE of upto 10% [12].

3. Degradation of Organic Solar Cells

Degradation of organic solar cells refers to the deterioration in their operational capacity. This deterioration does not necessarily occur always in the chemical structure of the OSC's. The degradations of OSC's can be subdivided into two groups, degradation under the effects of internal structure and induced by external factors. The significant part of the degradation is caused by the ambient air. Mass transfer (diffusion) is a concern in both degradation types. For example, OSCs having metal-organic intermediates stored under inert atmosphere environment has been shown to suffer significant degradation.



a) CuPc, C_{60} and P3HT b) PCBM[1] and PEDOT:PSS[1]

Figure 5. Chemical structures of OSCs built using common semiconductors (a: [1]; b:[13])

In organic solar cells, oxygen and water are two basic external factors that cause degradation. In the literature these two factors are mostly discussed. Oxygen is thought to be a dominant degradation parameter in organic solar cells, which is explained in the following way. Firstly, the water is not easily penetrating to the interior of the OSC. Secondly, due to the structure of the electron transport layer (ETL), the effect of oxygen is more visible and it directly affects the operating efficiency of the OSC. Third, it worsens operating stability of conventional OSCs as a result of damaging metal-formed interface layers[1].

Degradation Mechanisms	Likelihood	Approaches
Diffusion of oxygen and water	High	Device encapsulation Low OTR/WVTR adhesives
Photo-oxidation of polymers	Medium	Selection of stable active polymers; Device design
Electrode degradation (ITO and metal)	High	Optimization of metal electrode
Buffer layer degradation (PEDOT:PSS)	Medium	Optimization of HTL/ETL
Mechanical degradation (delamination, etc.)	Low	Adhesion improvement and lamination

Figure 6. Degrading mechanisms of OSCs and their likelihood to occur by [14]

Traditional OSCs would highly degrade under atmospheric conditions. Degradation Mechanisms and their likelihood of occurrence is given in the below table, which is taken from Solarmer Energy publications.As you can see, the high likelihood of occurrence is subject for Oxygen and Water along with the electron degradation. Therefore, as we tackle degradation from external factors, the only parameter to consider is water and oxygen.

As for some other materials being used in OSCs, oxygen may offer an also constructive effect in terms of electronic properties, since oxygen is typically a p-type dopant in semiconductors [1, 15], and oxygen vacancies serve as electron donors[16]. For that reason, for layers wherein the majority carrier are holes, the electronic properties may temporarily be enhanced when exposed to oxygen. Lira-Cantu et al. fabricated inverted organic-inorganic hybrid solar cells (HSCs) with a structure of ITO/oxides/MEH-PPV/Ag, and found that applying the semiconductor oxides, such as ZnO, or TiO_2, or Nb_2O_5, requires the presence of oxygen for the correct functioning of the semiconductor oxides as electron acceptors.[15] These HSCs degrade drastically under light irradiation in vacuum, but are partially recovered upon exposure to air.[1, 17] They proposed that the degradation is due to the removal of oxygen from the Nb_2O_5 surface under UV irradiation, whereas the recovery of performance in air comes from the reuptake of oxygen.[18]. Later, they proposed another oxygen-related mechanism to explain the photo-activation of OSCs, in which ZnO was used as the ETLs. In this case, however, the photoconductivity of ZnO was proposed to be activated upon exposure to UV irradiation .[19]

Oxygen-induced degradation in Organic solar cells is of external environment based degradations. This parameter is often discussed in the literature. Oxygen is dominant parameter in organic solar cells because of the factors given below:

-While allotrope materials do not react with water, they can easily react with the oxygen in the atmosphere. For example, while aluminum exhibits high strength in aqueous media this behavior is not possible with oxygen in the atmosphere.

-In allotrope materials oxygen can enter the electron transport layer very easily and lowers the operational efficiency of this layer.Improvements made on surface of metallic materials to prevent formation of pitting on these surfaces and hence the damage as a result of reaction with oxygen

In the literature, it has been explained in many studies that this parameter cause degradation to a lesser extent when compared to oxygen. While surface of Aluminum is observed to exhibit a good passivity in dry air, degradation on the surface is observed in a humid environment, however the degradation is shown to be quite small when compared to the degradation rate of oxygen.[1]

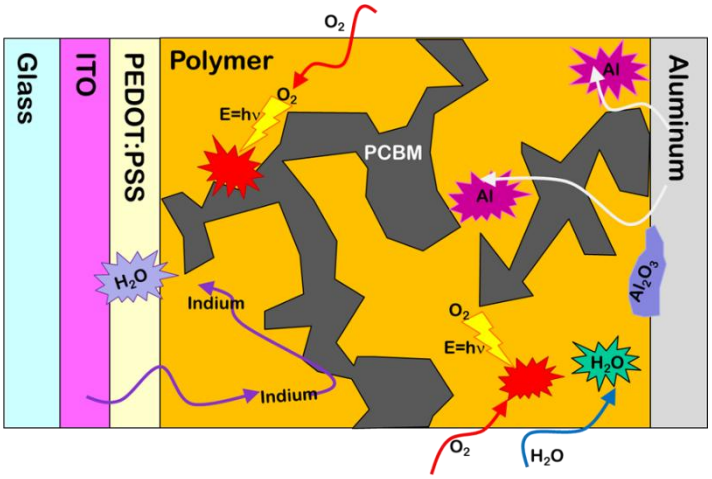


Figure 7.Schematic illustration ofdegradation with oxygen and water

OSCs manufactured in conventional architecture suffered severe degradation in air environment[20]. Later OSCs were begun to be produced with different techniques in order to reduce their susceptibility to hostile environments. And researches have revealed that a change in the planar and polar arrangement of the organic solar cells significantly reduce their vulnerability in such environments, and inverted OSC architecture was introduced. An Inverted organic solar cell is an OSC with its ETL and HTL is swapped along with the Anode and Cathode. Thus, we can classify the OSCs as conventional (anode directly on substrate) or inverted (cathode directly on substrate) according to which side is close to the substrate.

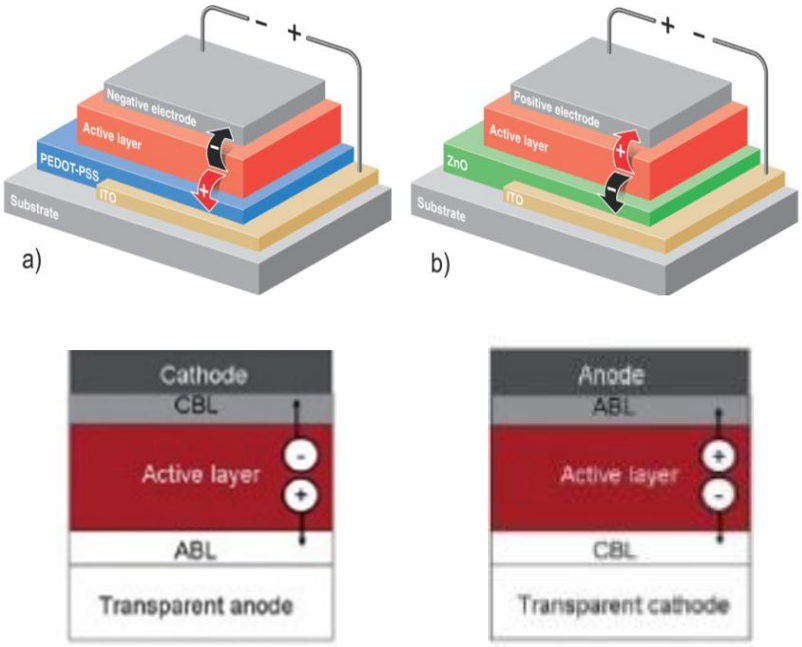


Figure 8. A Conventional (a) and inverted (b) solar cell [21]

The above Figure illustrates conventional and inverted organic solar cells. Although conventional and inverted OSCs are quite different in structure, their working principles are essentially the same. But examining the performance of the inverted structure in OSCs, it was found to protect the OSC from rapid degradation caused by some external factors.

Figure 9 shows the comparison of a conventional OSC and an inverted OSC in time domain. When this graph is examined, it will be seen that the sensitivity of the inverted OSC to this degradation parameter decreases. However, studies have shown that oxygen is still the fastest degrading parameter even for inverted OSCs[22].

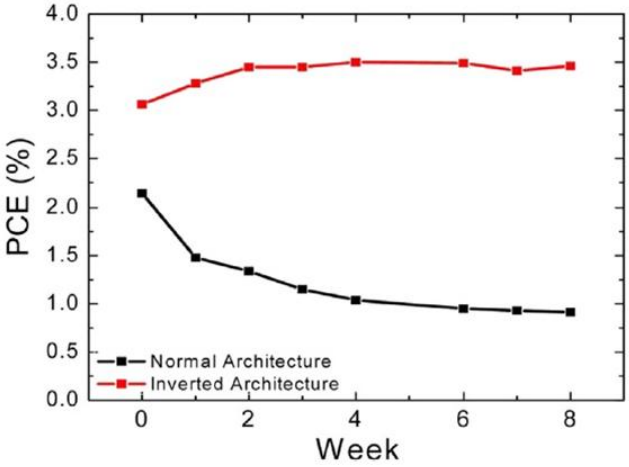


Figure 9. Comparison of Power Conversion Efficiencies of Conventional and Inverted OSCs[1].

The PEDOT:PSS component, which is the top layer of an inverted OSC, suffers significant degradation due to the phase change that oxygen causes[23].

According to *Wang et al.* they achieved a considerable improvement in CuPc/C60 solar cells, which they manufactured in a smaller molecular structure, by bringing it in a structure that is stable for 950 hours in the air environment[24]. They interpreted the reason to be that it takes longer for the moisture in the atmosphere to intrude the bottom layer of the OSC and diffuse into the PAL. In Figure 9, the Power Conversion Efficiencies (PCE) of OSCs with conventional (black) and inverted (red) architecture are plotted against time.

4. Conclusion

No need to mention again, OSCs should be stable, intrinsically and extrinsically. Furthermore, for the sake of flexibility, which modern solar cells really seem to need, ITO electrodes can be replaced with organic conducting materials, like PEDOT:PSS [25], or single-walled carbon nanotubes[26]. Finally, the organic semiconductors used in OSCs need to be chemically stable under solar irradiation[5, 27]. Stabilization of OSCs is structure dependent. In this section, we first briefly discuss a few ways of improving the intrinsic stability of OSCs, and then we discuss a few common ways of improving the extrinsic stability of conventional and inverted OSCs. Two general ways are to use metal oxides as the buffer layers, and silver as the top anodes. We further discuss two newly developed effective stabilization methods, with each only applicable to one type of structure. Titanium-aluminum can be used as the top cathode in conventional structures, whereas modified ITO can be used as the bottom cathode in inverted structures[1].

Degradation parameters have been found to have a significant impact on the operating stability of organic solar cells. In modern OSCs, these degradation parameters are tried to be minimized. Literature reports plenty of changes made to improve the operational stability of OSCs. In all these studies, the key is the development of a cathode-acceptor layer.

When the structure of an Inverted OSC is examined, it is obvious that a buffer layer is aimed to be formed by using Indium Tin Oxide polymer material as a lower layer, and metals, such as Ag, in the upper layer. With this change, the effect of moisture in the atmosphere on degradation of a conventional OSCs has been significantly reduced for in inverted OSCs. As a result, and the changes made in the design and in the layer structure of the organic solar cells will minimize the degradation and increase the operating stability of the system. Thus, the energy yield from solar cells will be increased.

References

[1] Cao, H.Q., et al., Recent progress in degradation and stabilization of organic solar cells. Journal of Power Sources, 2014. 264: p. 168-183.

[2] Yu, G., et al., Polymer Photovoltaic Cells - Enhanced Efficiencies Via a Network of Internal Donor-Acceptor Heterojunctions. Science, 1995. 270(5243): p. 1789-1791.

[3] You, J.B., et al., A polymer tandem solar cell with 10.6% power conversion efficiency. Nature Communications, 2013. 4.

[4] Jorgensen, M., et al., Stability of Polymer Solar Cells. Advanced Materials, 2012. 24(5): p. 580-612.

[5] Manceau, M., et al., Photochemical stability of pi-conjugated polymers for polymer solar cells: a rule of thumb. Journal of Materials Chemistry, 2011. 21(12): p. 4132-4141.
[6] Wang, F.Z., et al., Recent advances in planar heterojunction organic-inorganic hybrid perovskite solar cells. Acta Physica Sinica, 2015. 64(3).
[7] Bakulin, A.A., et al., The Role of Driving Energy and Delocalized States for Charge Separation in Organic Semiconductors. Science, 2012. 335(6074): p. 1340-1344.
[8] Group, T.R. and T.U.o.S. California. 2017 [cited 2017 23 May]; Available from: http://met.usc.edu/projects/solarcells.php.
[9] Schilinsky, P., et al., Simulation of light intensity dependent current characteristics of polymer solar cells. Journal of Applied Physics, 2004. 95(5): p. 2816-2819.
[10] Qi, B. and J. Wang, Fill factor in organic solar cells. Phys Chem Chem Phys, 2013. 15(23): p. 8972-82.
[11] Qi, B.Y. and J.Z. Wang, Open-circuit voltage in organic solar cells. Journal of Materials Chemistry, 2012. 22(46): p. 24315-24325.
[12] Scharber, M.C., et al., Design rules for donors in bulk-heterojunction solar cells - Towards 10 % energy-conversion efficiency. Advanced Materials, 2006. 18(6): p. 789-+.
[13] Wikipedia. 2017 [cited 2017 23 May]; Available from: https://en.wikipedia.org/wiki/PEDOT:PSS.
[14] Energy, S. 2017 [cited 2017 23 May]; Available from: http://solarmer.com/aboutus/.
[15] Song, Q.L., et al., Role of buffer in organic solar cells using C-60 as an acceptor. Applied Physics Letters, 2007. 90(7).
[16] Wahlstrom, E., et al., Electron transfer-induced dynamics of oxygen molecules on the TiO2(110) surface. Science, 2004. 303(5657): p. 511-513.
[17] Cuentas-Gallegos, A., et al., Electrochemical supercapacitors based on novel hybrid materials made of carbon nanotubes and polyoxometalates. Electrochemistry Communications, 2007. 9(8): p. 2088-2092.
[18] Vaillant, J., et al., Chemical synthesis of hybrid materials based on PAni and PEDOT with polyoxometalates for electrochemical supercapacitors. Progress in Solid State Chemistry, 2006. 34(2-4): p. 147-159.
[19] Krebs, F.C., T. Tromholt, and M. Jorgensen, Upscaling of polymer solar cell fabrication using full roll-to-roll processing. Nanoscale, 2010. 2(6): p. 873-886.
[20] Xi, X., et al., A comparative study on the performances of small molecule organic solar cells based on CuPc/C-60 and CuPc/C-70. Solar Energy Materials and Solar Cells, 2010. 94(12): p. 2435-2441.
[21] Li, G., et al., Efficient inverted polymer solar cells. Applied Physics Letters, 2006. 88(25).
[22] Sondergaard, R., et al., Roll-to-roll fabrication of polymer solar cells. Materials Today, 2012. 15(1-2): p. 36-49.
[23] Norrman, K., et al., Degradation Patterns in Water and Oxygen of an Inverted Polymer Solar Cell. Journal of the American Chemical Society, 2010. 132(47): p. 16883-16892.
[24] Wang, M.L., et al., Small-molecular organic solar cells with C-60/Al composite anode. Organic Electronics, 2007. 8(4): p. 445-449.
[25] Zhou, Y.H., et al., A Universal Method to Produce Low-Work Function Electrodes for Organic Electronics. Science, 2012. 336(6079): p. 327-332.
[26] Rowell, M.W., et al., Organic solar cells with carbon nanotube network electrodes. Applied Physics Letters, 2006. 88(23).
[27] Lee, J.U., et al., Degradation and stability of polymer-based solar cells. Journal of Materials Chemistry, 2012. 22(46): p. 24265-24283.

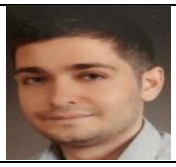
BIOGRAPHY OF AUTHORS

Efe Çetin YILMAZ was born in 1989. He received MSc degree from Mechanical Engineering the Ataturk University, Erzurum, Turkey, in 2014. Now, he is continuing from same University Ph.D. degree since in 2014. For five years, he has been working as a Lecturer in the Department of electronics and automation at Ataturk University. His areas of interest are control system design and programming, wear of biomaterials, corrosion and renewable energy.

Muhammet Kaan YEŞİLYURT was born in 1979. After he received his Bsc in 2003, he worked for many international companies, especially in oil and gas sector. Then he returned his academic career and received his MSc at Ataturk University in 2015. He is working as an Instructor at Pasinler Vocational School in Electric and Energy Department. He is now a PhD student at Ataturk University in Turkey.

İlhan Volkan ÖNERwas born in 1979. He received MSc degree in Mechanical Engineering at Ataturk University, Erzurum, Turkey, in 2009. Later, he received his Ph.D. degree also at Ataturk University in 2014. Since 2015, he has been working as an Assistant Professor in Department of Alternative Energy Sources at Ataturk University. His areas of interest are renewable energy, internal combustion engines and alternative fuels.

Gökhan ÖMEROĞLUwas born in 1982. He received Bsc, MSc and Ph.D degrees at Ataturk University in 2003, 2009, and 2012 respectively. He has started his career at Bayburt University as an Instructor. After receiving his Ph.D he has been assigned the Assistant Professor position at the same university, and shifted to Ataturk University the same year. Since then, he has been working as an assistant professor at Ataturk University Engineering Faculty, Department of Mechanical Engineering, Thermodynamics division.



Ahmet Numan ÖZAKIN was born in 1991. He has graduated from Mechanical Engineering Department in 2013 and has started his academic career the same year as a research assistant at Ataturk University. He received MSc degree in 2016 and he is still a PhD student and research assistant. His fields of interest and study are renewable and alternative energy systems, photovoltaic and photovoltaic thermal combi systems.

Note: This study has been extended and revised after been presented in 3rd International Conference on Engineering and Natural Science held on 3 – 7 May 2017 in Budapest, Hungary. It was previously published as Abstract in the Book of Abstracts of the conference.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June2017, pp. 161~164
Available online at:http://pen.ius.edu.ba

Estimation of Specific Gravity with Penetration and Penetration Index Parameters by Artificial Neural Network

Sercan Serin[1], Sebnem Karahancer[2], Ekinhan Eriskin[2], Nihat Morova[2], Mehmet Saltan[2], Serdal Terzi[2]
[1]Departement of Civil Engineering,Duzce University
[2]Departement of Civil Engineering, Suleyman Demirel University

Article Info

Article history:

Received May25th, 2017
Revised June14th, 2017
Accepted June16th, 2017

Keyword:

Artifical neural network
Specific gravity
Penetration
Penetration index

ABSTRACT

Specific Gravity of the bitumen changes according to the ambient temperature. Different specific gravity values can be calculated at different temperature. Estimating models like Artificial Neural Network – ANN could be very useful to obtain the specific gravity value uniform. Specific gravity values obtained from Long-Term Pavement Performance – LTPP were estimated with artificial neural networks. Penetration and Penetration Index of binder were used for estimating the specific gravity of the bitumen. As a result, ANN get 84% of R2 between obtained and estimated values.

Corresponding Author:

Sercan Serin,
Departement of Civil Engineering,
Duzce University,
Duzce University, Faculty of Technology, D Blok,81620, Duzce, TURKEY.
Email: sercanserin@duzce.edu.tr

1. Introduction

Current practices for asphalt mix design and acceptance testing rely on volumetric properties. Vital to the calculation of mix volumetric properties are specific gravity measurements of the mixture and the aggregate in the mixture. Superpave mix design is getting popular day to day and more recognized by researchers. The volumetric analyses provide the basis for the Superpave mix design method. Specific gravity of the materials is essential to calculate the volume of the mixture.

Specific Gravity of the bitumen changes according to the ambient temperature. Different specific gravity values can be calculated at different temperature. Estimating models like Artificial Neural Network – ANN could be very useful to obtain the specific gravity value uniform.

Pavement researchers have been widely using ANNs in diverse subjects during the past decade. ANNs have been successfully used by researchers to predict/back- calculate pavement moduli by training the ANNs using deflection data from falling-weight deflectometers [1-3]. Tutumluer and Seyhan [4] estimated the horizontal and shear moduli by using confining and deviator stresses of triaxial test, deformation and aggregate properties. Lacroix et al. [5] used the resilient moduli data to predict the dynamic modulus master curve of asphalt mixtures. Some researchers predicted the fatigue life of pavements with ANN-based methods [6-7]. Tarefder et al. [8] used ANNs to predict permeability of asphalt mixtures by using mixture variables such as air voids, grain size, saturation and effective asphalt-to-dust ratio.

Several researchers also developed models to determine the severity and type of the cracks with the help of ANN [9-12].

In this study, Specific gravity values obtained from Long-Term Pavement Performance – LTPP [13] were estimated with artificial neural networks. Penetration and Penetration Index of binder were included to the model.

2. Materials and Method

Data used in this paper is obtained from Long-Term Pavement Performance – LTPP [13]. For modelling these, penetration, penetration index and specific gravity data are get from the program. It's tried to obtain a relation between these parameters using ANN.
For predicting the specific gravity value of bitumen using ANN models, an appropriate selection of input parameters (neurons) is essential. There are two nodes in the input layer corresponding to two variables: penetration and penetration index of the bitumen. Model summary was seen in Table 1.

Table 1. ANN Model for specific gravity

Inputs	Number of Neuron	Number of Layers	Model	Output
Penetration Penetration Index	30-20-10	3	(2-30-20-10-1)	Specific Gravity

3. Research Findings

The relationship between obtained predicted values and measured values using the developed ANN model is shown in Figure 1. As it is illustrated in this figure, the predicted values are very close to experimental results, and this indicates a strong correlation between the input and output parameters of the ANN model. The R^2 values that are used to determine the significance of the ANN model.
From all parameters, 80% of parameters were selected as set of training randomly and the rest was selected as set of test (20%). Also the model was verified and tested. As seen from the Figure 1, training parameters were estimated as 100%, validation parameters were estimated as 98,6%, test parameters splitted by model were estimated as 98,5% and the all parameters were estimated as 92% of regression value by the model.

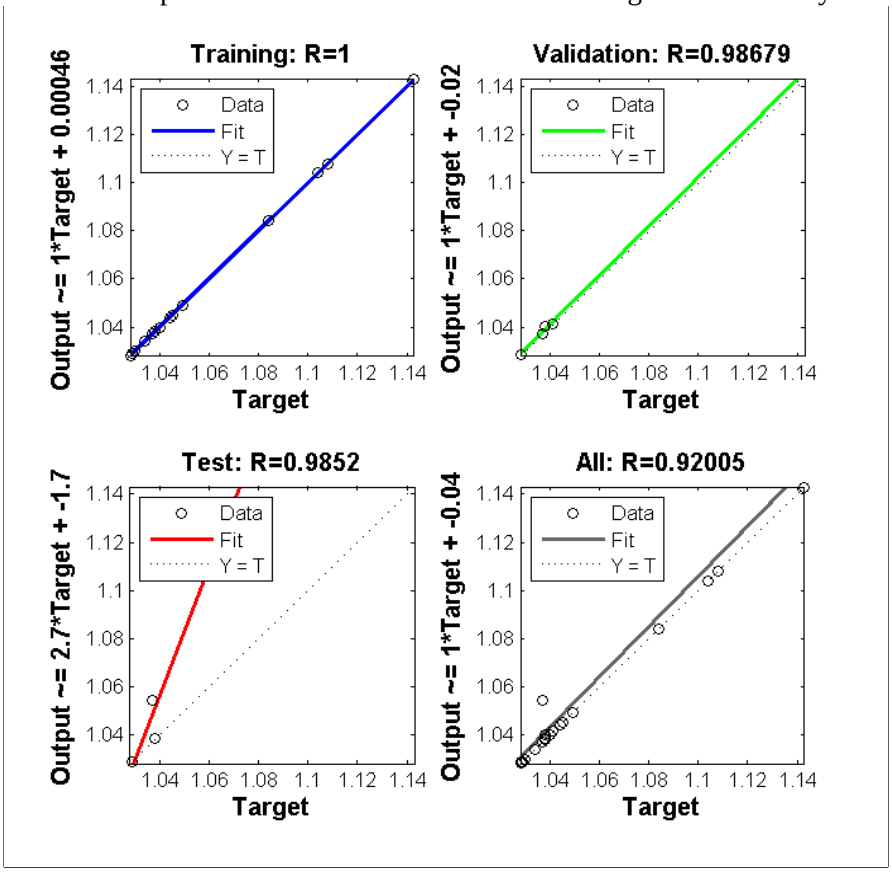


Figure 1. Relationship between the actual and predicted values by ANN for training data, validation data, testing data, and all data.

Input parameters of test parameters were given to the model after the model was trained successfully and output parameters were predicted. Obtained estimation results were compared to the real test results (Figure 2). Model predicted the test parameters successfully with R^2 value of 84%.

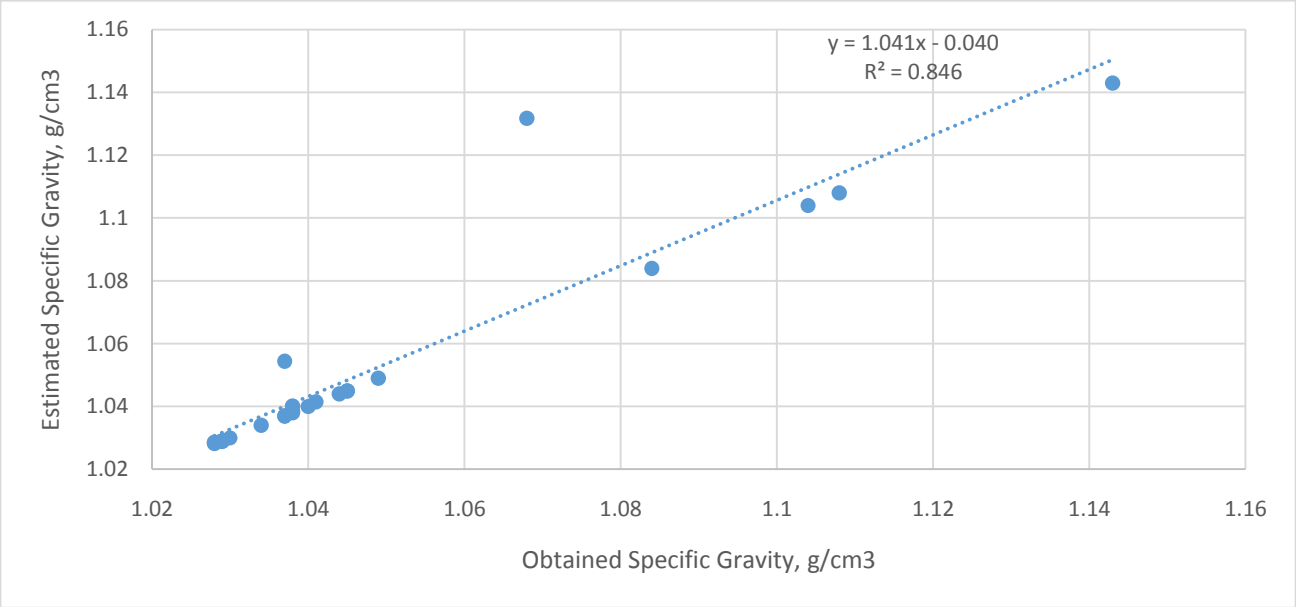


Figure 2. R^2 graph for test parameters of model

4. Results

In this study, an ANN method was developed to model the specific gravity of the bitumen for varying penetration and penetration index values of the bitumen. The ANN model predicted the test parameters successfully with regression value of 98%. The result indicates that the proposed model can be applied in estimating specific gravity of bitumen. The model is further applied to evaluate the effect of different values of penetration and penetration index on specific gravity.

References

[1] Y. Kim and R. Kim, "Prediction of layer moduli from falling weight deflectometer and surface wave measurements using artificial neural network." Transportation Research Record: Journal of the Transportation Research Board, 1639, 53–61, 1998.

[2] H. Ceylan, K. Gopalakrishnan and A. Guclu, "Advanced approaches to characterizing nonlinear pavement system responses." Transportation Research Record: Journal of the Transportation Research Board, 2005 (1), 86–94, 2007.

[3] A. Guclu and H. Ceylan, "Condition assessment of composite pavement systems using artificial neural net- works-based rapid backcalculation algorithms." TRB 86th annual meeting compendium of papers CD-ROM, 2007.

[4] E. Tutumluer and U. Seyhan, "Neural network modeling of anisotropic aggregate behavior from repeated load triaxial tests." Transportation Research Record: Journal of the Transportation Research Board, 1615, 86 – 93, 1998.

[5] A. Lacroix, Y.R. Kim and S.R. Ranjithan, "Back- calculation of the dynamic modulus from the resilient modulus of asphalt concrete using an artificial neural network." Transportation Research Record: Journal of the Transportation Research Board, 2057 (1), 107–113, 2007.

[6] C. Huang, Y.M. Najjar and S.A. Romanoschi, "Predicting asphalt concrete fatigue life using artificial neural network approach." In: Transportation Research Board Annual Meet- ing. Washington, DC, 2007.

[7] F. Xiao, A. Amirkhanian and C.H. Juang "Prediction of fatigue life of rubberized asphalt concrete mixtures contain- ing reclaimed asphalt pavement using artificial neural networks." Journal of Materials in Civil Engineering, 21 (6), 253 – 261, 2009.

[8] R.A. Tarefder, L. White and M. Zaman, "Neural network model for asphalt concrete permeability." Journal of Materials in Civil Engineering, 17 (1), 19–27, 2005.

[9] M.S. Kaseko and S.G. Ritchie, "A neural-network based methodology for pavement crack detection and classifi- cation." Transportation Research Part C: Emerging Technol- ogies, 1 (4), 275–291, 1993.

[10] S. Owusu-Ababio, "Effect of neural network topology on flexible pavement cracking prediction." Computer-Aided Civil and Infrastructure Engineering, 13, 349–355, 1998.

[11] Z., Lou, et al., "Application of neural network model forecast short-term pavement crack condition: Florida case study." Journal of Infrastructure Systems, 7 (4), 166–171, 2001.

[12] B.J. Lee and H.D. Lee, "A robust position invariant artificial neural network for digital pavement crack analysis." In: Transportation Research Board Annual Meeting. Washington, DC, 2003.

[13] FHWA, 2016, "Long Term Pavement Performance" Federal Highway Administration.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol. 5, No. 2, June 2017, pp. 165~175
Available online at: *http://pen.ius.edu.ba*

Sovereign Wealth Funds: A Comparison of the Turkish Sovereign Wealth Fund with the World Samples

Fatih GÜZEL[1], Melek ACAR[1], Gamze ŞEKEROĞLU[1]
[1]Departement of Business,Selcuk University

Article Info

Article history:

Received May 26th, 2017
Revised June 14th, 2017
Accepted June 17th, 2017

Keyword:

Portfolio management
Strategic planning
The Turkish Sovereign Wealth Fund

ABSTRACT

Sovereign wealth funds represent unity of assets that are directly or indirectly under public control and whose investments are largely concentrated across borders. Strategic objectives of the sovereign wealth funds are accumulating income surpluses for future generations or restoring the economic order and stabilizing it over the years when volatility is intense. Turkey decided the establishment of sovereign wealth fund in 2016. In this study, firstly, information on the practices of sovereign wealth funds is given. Then, the differences between the Turkish Sovereign Wealth Fund and existing samples are revealed. As a result, criticisms have been brought about the establishment and the operation process of the Turkish Sovereign Wealth Fund. Recommendations regarding the structure of the audit system and the management organization have been presented. The Turkish Sovereign Wealth Fund is a strategic step for Turkey, if it is managed properly, transparent and reliable.

Corresponding Author:

Fatih Güzel,
Departement of Business,
Selcuk University,
Alaeddin Keykubat Campus, Konya, Selçuklu 42250, Turkey.
Email: fatih_guzel1990@yahoo.com

1. Introduction

As a result of the structural transformations in economies after World War II and the rapid evolution of financial liberalization after the '80s, the importance of the economy has increased in politics and international relations. However, a robust economy, has become a significantly important weapon in the hands of the countries for being a center of power and balance in the international arena. Governments are constantly introducing new policies and new financial instruments to ensure stability alongside economic effectiveness. One of these instruments is the national wealth funds, which have different forms of practice in various countries. National wealth funds have been used for over 150 years, the real increase in the number of such funds has been experienced since 2000s. In addition to the quantitative increase, the expansion in economic size and the effective use of funds have led to intense debate in the perspective of the principles of budget unity and transparency in general. Despite this, more than 80 funds operate in more than 40 countries today.
In this study, information about national wealth funds, their place in the country's economy and the Turkish Wealth Fund are given. In addition, the Turkish Wealth Fund is compared with wealth funds in other countries, and critics and suggestions are presented.

1.1. National Wealth Funds and Purposes

Although sovereign wealth funds have been used in more than 150 years in economy management, they have made a major leap since the 2000s. The first example of the wealth fund was created in 1854 by the Texas State Legislature in the context of private-public service. On behalf of the benefit of education and public schools, the Texas Permanent School Fund was established with $ 2 million in grants. The sale and acquisition

of land owned by the state are shown as a source of funds [3]. In the present sense, national wealth funds have been operating since the 1950s and becoming increasingly important players in the international money and financial system. [4].
National wealth funds are used in different ways depending on socio-economic and cultural conditions [3]. The wealth fund is a pool of assets that are in the possession or control of the state, investing heavily in the assets of other countries [8]. Another definition is the state-controlled investment institution financed by the current surplus reserves of the country [5]. Although there are more explanations in the literature, there is no generally accepted definition. For this reason, it would be more descriptive to indicate common elements of wealth funds. Features that can be counted as common elements [29]:

- National wealth funds are state owned.
- The liabilities to the other side are very limited or none at all. This increases risk appetite.
- It is managed separately from official foreign exchange reserves. Because investment objectives and areas are different from each other.
- Most or all of the fund is invested in foreign assets.

While some countries create more than one wealth fund for a single target, others use one fund to reach different targets [9]. Generally, the types of funds created by governments and the purposes they serve are listed as follows [14], [15]:

- **Stabilization funds:** Countries with rich natural resources are set up to isolate the budget and the economy from the volatility of commodity (usually oil) prices. Funds are created for years with high fiscal year revenues and prepared for years when there is a downward trend.
- **Saving funds:** Funds are established to transfer richness and wealth to future generations. Countries with rich natural resources are transferring savings funds obtained from non-renewable sources to an internationally diversified portfolio to transfer to future generations or to achieve other long-term goals.
- **Reserve investment companies:** Funds set up to reduce the negative carrying costs of assets to be held as reserves or to monitor higher return on investment policies and to increase the reserve profitability. Often, assets in this context preserve the reserve nature.
- **Development funds:** Funds set up to finance industrial socio-economic projects, such as infrastructure, or to support industrial policies that could increase the output growth of the country.
- **Retirement reserve funds:** The provisions made for non-cocntingent pension liabilities (from sources other than private pension contributions). These funds are the source of reserves for payments that may arise from unpredictable dates and amounts of pensions.

In summary, the main objectives of wealth funds are to assess savings effectively and in the long run, to protect the economy against crises, to reduce imbalances between economies, to provide economic prosperity to future generations and to increase the international effectiveness of the country [1][24].
Income from balance-of-payments, official foreign exchange transactions, privatization revenues, fiscal surpluses and / or commodity issues constitute the basis for national wealth funds. [18]. In order to establish the wealth fund, there is a need for income surplus than the source selection. Depending on the nature of the surplus resource, the funds may be subject to a general classification as commodity based or non-commodity-based [32]. Commodity-based funds are based on the income generated from the exported assets. Natural gas, especially petroleum, copper and minerals are the commodities that provide resources for wealth fund. Funds that are not based on commodity are based on pension funds and foreign trade surplus, etc.

1.2. The Place and Importance of the National Wealth Funds in the Economy

The wealth fund will present a very high value added outcome, such as acquiring companies and managing global brands, expanding the current marketplaces, and providing competitive advantage with new information and technologies. Naturally, the return on such an investment is not limited to that. As a result of the trade made through this company, the company's customers, suppliers, and stakeholders in general terms will provide value added [26]. Another way to get a global company is to buy a company or merger. For these activities, large-scale funds are needed. One of the sources that have been actively used for economic development in the last half century is the sovereign wealth funds. Wealth funds differ because of systematic resource transfer from public savings, the ability to be a stabilization tool, and a longer-term investment horizon compared to other funds [31]. Company investments are not a goal for wealth funds, but rather a step where the fund rises above to its targets. Wealth funds aim to protect the income generated by the country's natural resources from political aspirations and conflicts and use it for the well-being of its citizens and future

generations. In addition, overvaluation of the country's money due to the surplus of income and the reduction of the competitive advantage of the country (Dutch Disease) are also indirectly a reason for the establishment of wealth funds [30].

The past half-century and especially the 2000's, have been a period in which structural breakdowns for the world economy have experienced one after another and economic crises have affected long years. Governments have also established wealth funds as a stabilization tool, as well as taking a variety of measures to prevent or mitigate economic devastation. Sovereign wealth funds have been tasked with a breakwater mission, to prevent the volatility and crisis from worsening the economy. In Figure 1 [19], sovereign wealth funds are grouped according to the years they are established. After 2000, the increase in the number of funds is noteworthy. Two thirds of the sovereign wealth funds were established after this date.

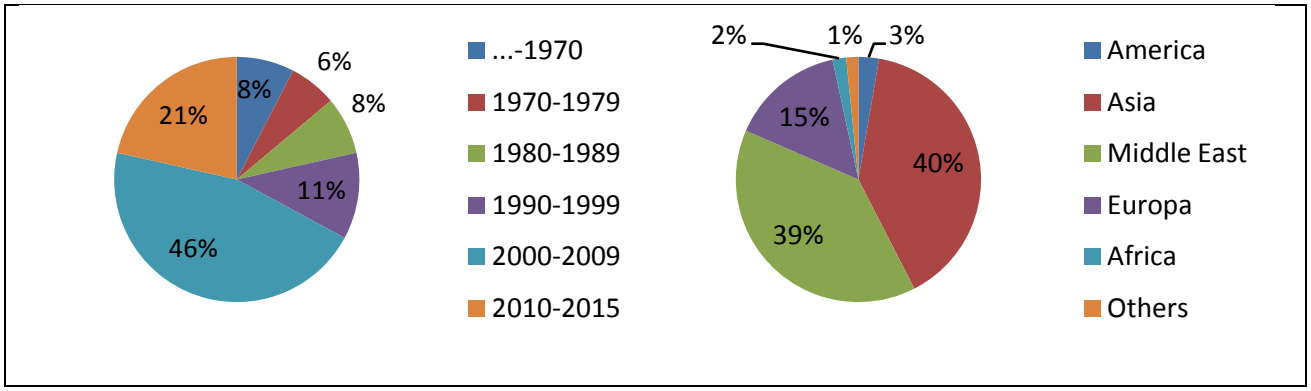


Figure 1. Sovereign Wealth Funds by Years and Region

The reason for the rapid increase in the number of sovereign wealth funds in recent years is high natural resource and commodity prices. Moreover, governments' high foreign exchange reserves and fiscal resource policies are also supporting this increase. National wealth funds are, in essence, the symbols of the latest trends in the global political economy. These funds can be expressed as a demonstration of the transfer and distribution of the economic and financial power from the US, Europe and other developed industrial countries to countries where is less, and the increasing effectiveness of governments in managing the wealth and economic power of the world today [6]. Figure 1 also shows regional distribution of wealth funds established. In general, most of the funds are in the Middle East and Asia region, which is the majority of developing countries.Sovereign Wealth Funds shows that the ownership of capital in a globalized economy is dispersed to peripheral countries. In the global financial system, countries other than Japan, USA and European countries are now playing an active role [8]. In order to measure the impact of sovereign wealth funds on global financial markets the economic magnitudes of funds should be considered [29]. Table 1 contains the top 10 funds having the largest economic size [19].

Table 1. National Wealth Funds Profile by Economic Growth (2016)

Country	**Name of Wealth Fund**	**Assets (Bil. US $)**	**Inception**	**Origin**
Norway	Government Pension Fund - Global	870.81	1990	Oil
China	China Investment Corporation	813.8	2007	Non-Commodity
UAE-Abu Dhabi	Abu Dhabi Investment Authority	792	1976	Oil
Suudi Arabia	SAMA Foreign Holdings	576.3	1952	Oil
Kuwait	Kuwait Investment Authority	592	1953	Oil
China	SAFE Investment Company	474	1997	Non-Commodity
China –Hong Kong	Hong Kong Monetary Authority Investment Portfolio	456.6	1993	Non-Commodity
Singapore	Goverment of Singapore Investment Corporation	350	1981	Non-Commodity
Qatar	Qatar Investment Authority	335	2005	Oil&Gas
China	National Social Security Fund	295	2000	Non-Commodity
Total (10)		**5,555.51**		
Total (All)		**7,409.74**		

A comparison can be made to understand the economic magnitude of sovereign wealth funds. The total economic size of the funds is about 10% of the total gross domestic product of all countries and about 10 times bigger than the Turkish economy [13]. With its growing volumes, wealth funds have faced investment allowances and management risks in the current global investment environment. Sovereign wealth funds are an important and growing investor class with one of the world's largest pools of institutional assets [17]. For this reason, the difficulties of managing their own portfolio lines are the biggest challenge for wealth funds. Figure 2 [17] shows the investment strategies of sovereign wealth funds.

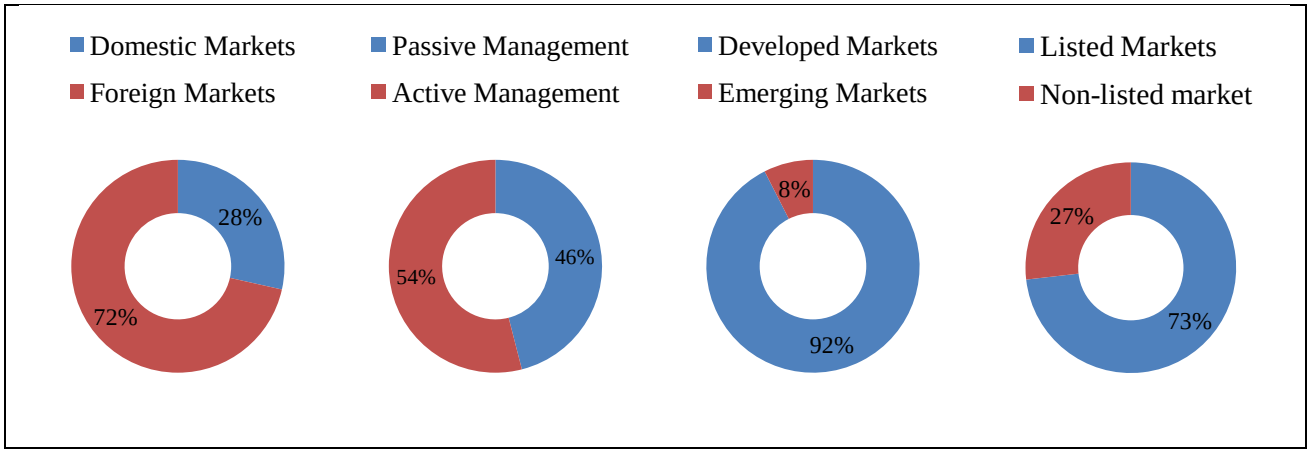
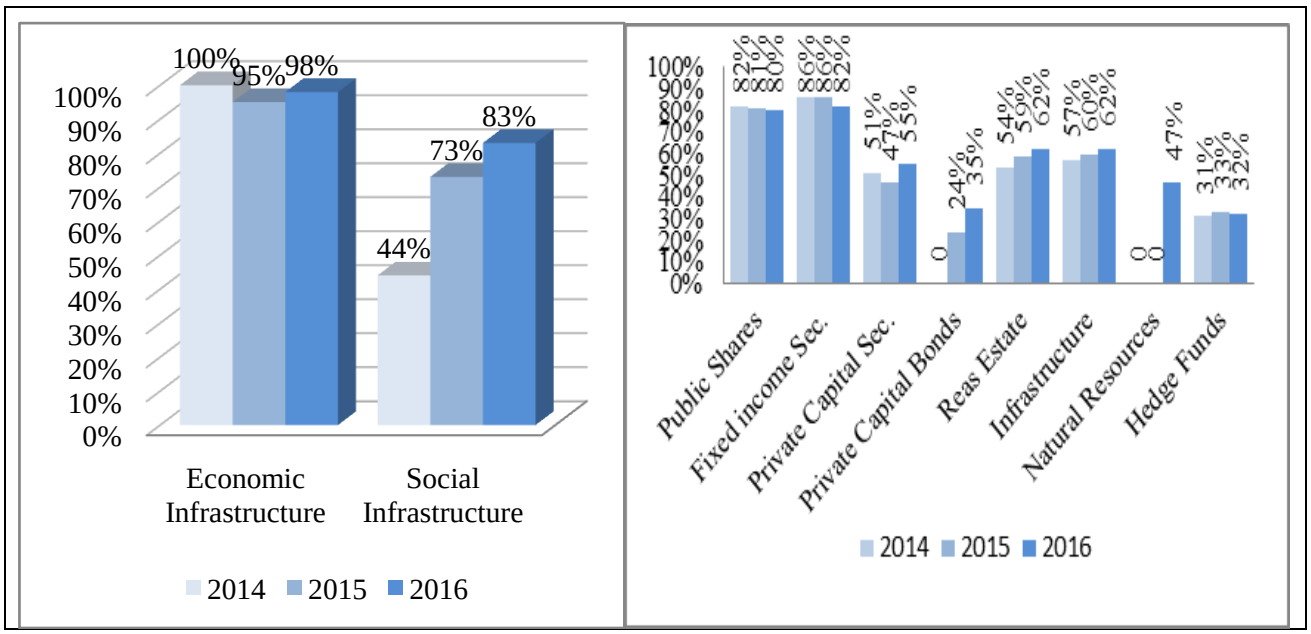


Figure 2. Sovereign Wealth Fund Asset Allocation, July 2016

As shown in Figure 2, the ratio of active and passive management strategies in the management of sovereign wealth funds is very close. There can be many reasons for this. However, long-term prospects and applications is a major cause of the rise in the rate of passive management strategy. In addition, an important point in Figure 2 is that 70% of the wealth fund is invested out of the country where the fund is located and provided resource. However, almost all of the funds were directed to the industrialized countries. It seems that the investment preferences of wealth funds favor the areas where the free float ratio is high.



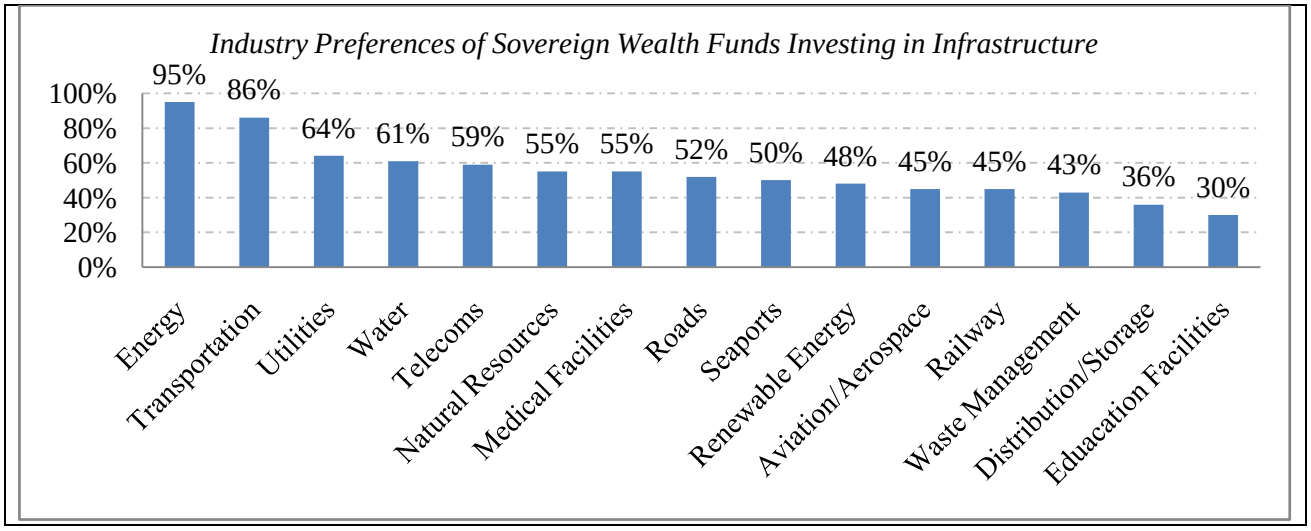


Figure 3. Investment Portfolio of Sovereign Wealth Funds (2014-2016)

Figure 3 [20] provides more detailed information on investment allocations of wealth funds between the years 2014-2016. When Figure 3 is examined, investment appetite for public stocks, fixed income instruments and hedge funds have decreased, and a steady increase in private equity corporate bonds, real estate and infrastructure investments have been experienced. However, the ratio of investors in infrastructure investments to the total number of investors in these areas is 75%. This ratio is 14% in real estate, 4% in private equity and 7% in other areas. This data shows that wealth funds are used as a means of stability and development in line with the general purpose of the establishment. The increase in the number of investors operating in social infrastructure also supports this idea. More than half of wealth fund investors are more interested in investments in energy, transportation, utilities, water, communications, natural resources, health care, road and port.

Sovereign wealth funds have become quite a big economy by the end of the 2000s. The lack of an audit framework, which is caused by the fact that the funds are excluded from many regulations due to their economic size and legal structure, has been a matter of concern. In order to overcome for these concerns, The International Working Group of Sovereign Wealth Funds has been established as a result of negotiations with global groups such as the IMF, the FED and the G20 countries. In 2009, the institution changed its name as International Forum of Sovereign Wealth Funds. In 2008, the Institution published the "Generally Accepted Principles and Practices" statement known as "Santiago Principles" in the context of corporate governance and risk management [25]. The Forum will contribute to the development and maintenance of an open and stable work environment and thus support the four guiding objectives underlying the Santiago Principles. These objectives are [12]:

- Assisting in the free circulation of capital, investments and the preservation of the stability of the global financial system,
- To fulfill the valid, explanatory and regulatory requirements of the invested country,
- Invest in risk and return based on economic and financial factors,
- To have a transparent and sound management structure that ensures adequate operational control, risk management and accountability.

The Santiago principals are based on volunteerism and are not internationally binding. However, it is a prerequisite for entry into US and European markets. Therefore, funds strive to comply with the relevant principles [8], [21].All funds within the sovereign wealth fund do not comply equally with the Santiago Principles. For this reason, an index has been developed by Carl Linaburb and Michael Maduell in the Sovereign Wealth Fund Institute (SWFI), a pioneer in research and documentation on wealth funds, to measure the level of information sharing with the public [11].The index is referred to by its founders and is known as the Linaburg-Maduell Index. The index is used globally, is included in annual reports of funds, and functions as a standard global benchmarking tool. The index consists of 10 items and each item is worth one point [16].

2. Turkish Sovereign Wealth Fund

The Turkish Wealth Fund (TWF) was established on the date of publication in the Official Gazette on August 26, 2016 by the Law No. 6741 "Amendment of the Law on the Establishment of the Turkish Wealth Fund Management Joint Stock Company". Information on TWF's purpose, scope, management and supervision, resources and economic size are given below.

2.1. The Turkish Wealth Fund's Purposes and Field of Activity

The aims of TWF [23] are:
- To contribute to the diversity and depth of the capital market instruments,
- To bring in the assets belonging to the public in the country into the economy,
- To provide foreign investment,
- To establish and manage subsidiary funds in order to participate in strategic and large-scale investments.

With the establisment of the fund, in addition to the above mentioned items, the law draft submitted to the Grand National Assembly of Turkey (TGNA)with not being included in the text of the law and legislative intention [22], it is targeted that:
- An additional 1.5% increase in growth rate over the next 10 years,
- Acceleration of growth and deepening of capital markets,
- Dissemination of the use of Islamic finance instruments,
- Additional employment for hundreds of thousands of people with investments to be made,
- Ensuring that domestic players are supported by capital and projects in technology-intensive strategic sectors such as defense, aviation and software,
- Financing of large infrastructure projects without raising public sector debt,
- Increasing the share of participation finance sector,
- Direct investment in strategic sectors such as natural gas and oil, which are important for Turkey in order to ensure security of supply, without being subject to legal and bureaucratic restrictions.

In addition, the fund has been assigned to be an instrument to contribute to overcoming the structural problems of the Turkish economy and to enhance the effectiveness of Turkey at the international level. Within the scope of Article 2 of Law No. 6741, the transactions that can be made by TWF considering the liquidity, investment, risk and return preferences in order to reach its targets are as follows:
- Purchase and sale of the shares of domestic and foreign companies, the shares of the issuers in Turkey and abroad and the debt instruments, the capital market instruments issued based on precious metals, fund participation shares, derivative instruments, lease certificates, real estate certificates, custom designed foreign investment instruments and other instruments,
- All kinds of money market transactions,
- Evaluation of real estate, rights based on real estate and all kinds of immaterial rights,
- All kinds of project development, project based resource creation, external project loan provision and other methods of providing resource,
- All kinds of commercial and financial activities are carried out at national and international primary and secondary markets. The company may participate with national investments to the investments to be made in other countries and / or foreign companies in the international arena.

2.2. Management and Supervision of the Turkish Wealth Fund

The TWF is directly linked to the Prime Minister for management. The president, members and general manager are appointed by the Prime Minister in the board of directors consisting of at least five members. As the appointment criteria, the president, members and general manager are required to have experience more than five years in at least one of the fields of economy, finance, law, finance and banking.
Sub-funds within the TWF will be managed within the framework of a three-year strategic investment plan, which is prepared by the company and the board of directors and is in force with the approval of the Council of Ministers. The organization, structure, functioning, management and transactions of TWF related funds shall be determined within the provisions of TWF's internal regulations and company's articles of association. [23]. The Board of directors meetings can be held with the absolute majority of the total members. The

decisions of the board of directors may be taken by the absolute majority of the members attending the board meetings [1].

TFV management has the obligation to comply with the corporate governance principles and regulations under the Capital Markets Law No. 6362. TWF and its sub-funds will be subject to independent audit. Financial statements of the TWF, sub-funds, company and affiliated companies will be audited by at least three central auditors appointed by the Prime Minister. These auditors are specialized in capital markets, finance, economy, treasury, banking and development. Prepared report as a result of the audit is presented to the Council of Ministers by the end of June every year and is examined annually in October by the Planning and Budget Commission of the TGNA through audit reports [23]. With this arrangement, a triple control mechanism is ensured.

TWF management is structured as a joint stock company in the private company status. It is subject to the Law on the Chamber of Accounts, the Civil Servants Law, the Public / State Procurement Law, the laws on privatization, the laws of the State Economic Enterprises (SEEs), and the law on the Supervision of the TGNA on Funds and SEEs. In addition, the fund is exempt from VAT and not subjetct to the Capital Markets Law, the Competition Law and income tax, corporation tax, real estate tax, stamp tax, bank and insurance transaction tax, resource utilization support fund withdrawal and some transactions [1].

2.3. Resources and Economic Size of TWF

The capital of the TWF management company, which is TL 50 million , was provided by the Privatization Fund. Full paid capital stocks belong to the Privatization Administration. On 24 January 2017, TL 3 billion belonging to the Industrial Support Fund was transferred to TWF on condition of reimbursement for three months' usage. On January 31, 2017, certain entities and treasury-owned real estate were transferred to the wealth fund [2]. Table 2 lists the companies transferred to TWF.

Table 2. Transferred Corporations to the Turkish Wealth Fund (February 2017)

Corporations	**Treasury Shares (Transferred assets)**	**Capital**	**Assets**
T.R. Ziraat Bankası Inc.	100,00%	TL 5.100.000.000	TL371.881.925.000[1]
Halkbank Inc.	51,11%	TL 1.250.000.000	TL237.726.267.000[1]
BOTAS Petroleum Pipeline Corporation	100,00%	TL 4.145.000.000	TL20.312.158.318[2]
Turkish Petroleum Corporation	100,00%	TL 3.000.000.000	TL10.981.613.631[2]
Turkish Post Inc.	100,00%	TL 981.530.194	TL3.980.492.637[2]
Borsa Istanbul Inc.	73,60%	TL 423.234.000	TL7.873.409.000[2]
Turkish Airlines Inc.	49,12%	TL 1.380.000.000	TL47.638.000.000[2]
Turk Satellite Communication Cable TV and Operation Inc.	100,00%	TL 1.474.816.334	TL1.980.870.355[1]
Turk Telecom Inc.	31,68% (6,68%)	TL 3.500.000.000	TL26.874.451.000[1]
Eti Mine Works	100,00%	TL 600.000.000	TL3.037.800.000[2]
Caykur	100,00%	TL1.492.400.000	TL2.072.400.000[2]
TOTAL		**TL 23.346.980.528 (=$ 6.342.909.294)**	**TL734.359.386.941 (=$ 199.510.809.319)**
[1]= 2016 **[2]= 2015**			

In addition to the companies listed in Table 2, all winning games licenses owned by the National Lottery are transferred to the TWF. Authorities of the Turkish Jockey Club for domestic and international joint bets and real estates owned by them are also transferred to TWF. In addition to this, the allocations on 46 public buildings in Antalya, Aydın, Isparta, Istanbul, İzmir, Kayseri and Muğla totaling 2,292,815 square meters were canceled and transferred to TWF [2]. At present, the wealth fund has TL 23 billion of equity capital and

reached TL 734 billion in asset size. With an asset size of approximately $ 196 billion and a large number of real estate, TWF can be seen as one of the attention grabbingfunds among world wealth funds.

3. Comparison of The Turkish Wealth Fund with Other Wealth Funds

TWF is different from the world's examples both quantitative and qualitatively. TWF will use the securitization of publicly owned companies, public properties, revenues from privatization transactions, and transactions to be carried out in the capital market as resources. However, when we look at the applications in the world in general, it is seen that the source of wealth funds is the budget surplus, trade or commodity export revenues such as oil, mineral resource, natural gas. In terms of the resources, it is obvious that TWF follows a different path from the examples in the world. But the lack of capital and technology are the biggest problems experienced by developing countries. TWF is a major capital resource. The Fund will support technology-intensive sectors such as defense, aviation and software, and will provide an opportunity to increase competitive advantage by providing high know-how with international partnerships and to raise the country's upper middle income to upper income level [10].

Wealth funds are generally established for saving. The goal is to allocate resources in the years when economic welfare is experienced, and to support prosperity in the years when it is reduced. Another objective is to transfer income from resources will be exhausted future generations and to share it with them. TWF will serve as an inexpensive outsourcing tool for the financing of very large-scale investments to be made [27]. Clearly, TWF does not have the essence of wealth funds, because it carries expenditure fund features instead of a savings fund. However, among the targets, the diversity of instruments in the capital markets and the importance given to Islamic finance applications, both the fund and the private sector will be able to reach cheaper financing sources at national and international scale. In addition, the fact that Islamic financial institutions in Turkey can directly reflect national transactions on international market shares will increase the efficiency of the sector. It is a good decision to support this sector which has not received open support by public until today. However, it is a fact that these goals do not match with the practice in the world. Supporting Islamic finance by increasing the share of participation banks is not among the objectives any other wealth fund.

In terms of auditing, TWF differs from other funds in the world. Given the international framework is generally true as the application that independent audit firms take part in the supervision. However, supervision with three auditors appointed by the Prime Minister is of concern in two respects. The first is that both the management and the control mechanism are managed from the same hand, which is an application open to misconduct. The second is that the number of central supervisory staff is at least three. The adequacy of a three-person team should be questioned to supervise an enormous economic organization of TL 734 billion. Moreover, the fact that these supervisory auditors are public servants contradicts the independence principle of the supervisor. Instead of leaving the audit duty of the Fund to the TGNA and sending the audit reports directly to the TGNA, it is a more correct approach to leave the audit to the Chamber of Accounts [28].

The most criticized point is contrariness to the principle of unity of the budget. In the general applications of wealth funds in different countries income is transferred to the fund, while TWF has income generating sources directly. The negative effects of the multi-budget system were evident at the beginning of the 1980s, 1990s and 2000s, and the effects of separately funded funds in the crisis have been discussed for many years. The disadvantages of this system are the reduction of income of the central budget, the loss of expenditure priorities [32]. At this point, it is vital that the fund management should constitute and implement the three-year strategic investment plan in a budget-supporting manner.

Companies with very different qualities from different sectors have been transferred to TWF as resource. This situation differs from other wealth fund applications. The fact is that the Fund has unfair competitive advantage over the market forces during the activities it will undertake when considering the diversity of activities and the exempted laws. For example, where will the banks in the portfolio be located in the regulations of the Banking Regulation and Supervision Agency (BRSA), how will the Capital Market Law be operated in the process of securitization of assets and how will their income be taxed? There are serious gaps in terms of legal regulations [7]. It is extremely important that the relevant legal regulations should be made as soon as possible.

4. Conclusion

Wealth funds, established for a wide variety of purposes, are generally endeavoring to support the economy and increase the level of prosperity. Regardless of the level of development, many countries are benefiting from wealth funds. Turkey has established a sovereign wealth fund in order to provide funds for strategic and large scale investments in general. The companies that are transferred to the fund are the locomotive firms of their sectors and make profit in large quantities. Therefore, transferred assets and companies can be considered as the most valuable companies of Turkey. The Fund may provide a high amount of credit from the market under appropriate conditions by showing these assets as collateral. In addition to cash return gained from these credits through effective evaluation of market conditions, it is possible to obtain value added such as diversification of market and customer portfolio with international investments to be made.

However, the current regulations concerning the selection and supervision of the management cadre are the greatest handicap in terms of the effectiveness of the fund and its independent implementation of its policies in line with macroeconomic developments. The fact that the fund management is seen as a unit attached to the executive authority is the greatest danger in terms of fund independence, success and impartiality. Independence is an important threshold for success. At this point, at least one of the management and supervision mechanisms seems to have been passed to the Assembly by the Prime Minister.

Besides the establishment and supervision of the Fund, management at international standards is important in terms of the enforcement of the investments to be carried out and the markets in which they can be influenced. The press conference and the written explanations emphasize the adoption of the Santiago Principles. This has a key prefix for entry into European and US markets, where value added is high. With the transparency and professional management to be provided in accordance with the principles, the fund will be able to achieve its stated objectives.

Turkey has a great opportunity with TWF. In today's turbulence macroeconomic environment, a structure that will support the economy has become compulsory. However, the fact that such a large economic organization operates separate from treasury may be regarded as a deviation from the budgetary unity which is one of the cornerstones of economic stability. As a result, Turkey's international voice may be louder, while using the resources efficiently it has. The Turkish Wealth fund's activities in the free market, not in the midst of political conflicts, have a vital importance to the success of the fund.

References

[1] İ. Özkul, «*11 soruda tüm yönleriyle Türkiye Varlık Fonu*» 10 Şubat 2017. [Online]. Available: http://www.dunya.com/ekonomi/11-soruda-tum-yonleriyle-turkiye-varlik-fonu-haberi-349431. [Date of Access: 10 February 2017].

[2] Official Gazette, «*5 Şubat 2017 Tarihli ve 29970 Sayılı Resmî Gazete - Mükerrer*» 5 February 2017. [Online]. Available: http://www.resmigazete.gov.tr/eskiler/2017/02/20170205M1.htm. [Date of Access: 15 February 2017].

[3] M. N. J. Firzli ve J. M. Franzel, «*Non-Federal Sovereign Wealth Funds in the United States and Canada: Public Asset Accumulation and Investment in Developed Economies*» *Revue Analyse Financière,* no. 52, pp. 6-8., September 2014.

[4] S. Willson, «*IMF Survey: Wealth Funds Group Publishes 24-Point Voluntary Principles*» 15 October 2008. [Online]. Available: https://www.imf.org/en/News/Articles/2015/09/28/04/53/sonew101508b. [Date of Access: 20 February 2017].

[5] S. Akbulak ve Y. Akbulak, «*Ulusal Varlık Fonları*» *Marmara Üniversitesi İ.İ.B.F. Dergisi,* cilt 25, no. 2, pp. 237-262., 2008.

[6] E. M. Truman, «*Sovereign Wealth Funds: Threat or Salvation?*» Washington: Peterson Institue for International Economics, 2010.

[7] N. Saygılıoğlu, «*Türkiye Varlık Fonu Hakkında Akla Takılan Sorular*» 8 Şubat 2017. [Online]. Available: http://www.dunya.com/kose-yazisi/turkiye-varlik-fonu-hakkinda-akla-takilan-sorular/349066. [Date of Access: 8 Şubat 2017].

[8] H. Aykın, «*Ulusal Refah Fonları:Risk mi, Fırsat mı?*» 2011. [Online]. Available: http://www.sde.org.tr/tr/newsdetail/-ulusal-refah-fonlari-risk-mi-firsat-mi-analizi/2725. [Date

of Access: 20 Şubat 2017].

[9] I. Petrova, J. Pihlman, P. Kunzel ve Y. Lu, «*Investment Objectives of Sovereign Wealth Funds : A Shifting Paradigm*» January 2011. [Online]. Available: https://www.imf.org/external/pubs/ft/wp/2011/wp1119.pdf. [Date of Access: 17 January 2017].

[10] Ş. Manukyan, «*Varlık Fonu Dinamikleri Nelerdir? Global Örnekler*» 10 Şubat 2017. [Online]. Available: http://www.dunya.com/kose-yazisi/varlik-fonu-dinamikleri-nelerdir-global-ornekler/349407. [Date of Access: 10 Şubat 2017].

[11] M. Ercan, «*Ülke varlık fonlarının önemi ve yapısı*» 7 Eylül 2013c. [Online]. Available: http://www.radikal.com.tr/yazarlar/metin-ercan/ulke-varlik-fonlarinin-onemi-ve-yapisi-1149687/. [Date of Access: 13 Şubat 2017].

[12] IFSWF, «*Establishment of the International Forum of Sovereign Wealth Funds*» 6 April 2009. [Online]. Available: http://www.ifswf.org/santiago-principles-landing/kuwait-declaration. [Date of Access: 28 January 2017].

[13] The World Bank, «*GDP Ranking*» 1 February 2017. [Online]. Available: http://data.worldbank.org/data-catalog/GDP-ranking-table. [Date of Access: 8 February 2017].

[14] IMF, «*Global Financial Stability Report*» October 2007. [Online]. Available: https://www.imf.org/External/Pubs/FT/GFSR/2007/02/pdf/text.pdf. [Date of Access: 2 February 2017].

[15] IMF, «*IMF Survey: IMF Intensifies Work on Sovereign Wealth Funds*» 4 March 2008. [Online]. Available: https://www.imf.org/en/News/Articles/2015/09/28/04/53/sopol03408a. [Date of Access: 3 February 2017].

[16] SWFI, «*Linaburg-Maduell Transparency Index*» 2017c. [Online]. Available: http://www.swfinstitute.org/statistics-research/linaburg-maduell-transparency-index/. [Date of Access: 21 February 2017].

[17] IFSWF, «*New Challenges, Private Markets: Sovereign Wealth Funds' Changing Investment Strategies*» November 2016. [Online]. Available: http://www.ifswf.org. [Date of Access: 21 February 2017].

[18] IMF, «*Setting up a Sovereign Wealth Fund: Some Policy and Operational Considerations*» August 2009. [Online]. Available: https://www.imf.org/external/pubs/ft/wp/2009/wp09179.pdf. [Date of Access: 15 January 2017].

[19] SWFI, «*Sovereign Wealth Fund Rankings*» 2017a. [Online]. Available: http://www.swfinstitute.org/sovereign-wealth-fund-rankings/. [Date of Access: 21 February 2017].

[20] PREQIN, «*Sovereign Wealth Funds Investing in Infrastructure*» May 2016. [Online]. Available: https://www.preqin.com/docs/newsletters/ra/Preqin-Real-Assets-Spotlight-May-2016.pdf. [Date of Access: 1 March 2017].

[21] IWG, «*Sovereign Wealth Funds: General Accepted Principles and Practices*» October 2008. [Online]. Available: http://www.ifswf.org/sites/default/files/santiagoprinciples_0_0.pdf. [Date of Access: 8 February 2017].

[22] TGNA, «*Türkiye Varlık Fonu Kurulması ile Bazı Kanun ve Kanun Hükmünde Karanamelerde Değişiklik Yapılmasına Dair Kanun Tasarısı*» 1 Ağustos 2016. [Online]. Available: http://www2.tbmm.gov.tr/d26/1/1-0750.pdf. [Date of Access: 2 Mart 2017].

[23] Official Gazette, «*Türkiye Varlık Fonu Yönetimi Anonim Şirketinin Kurulması İle Bazı Kanunlarda Değişiklik Yapılmasına Dair Kanun*» 26 Ağustos 2016. [Online]. Available: http://www.resmigazete.gov.tr/eskiler/2016/08/20160826-1.htm. [Date of Access: 4 Şubat 2017].

[24] SWFI, «*What is a SWF?*» 2017b. [Online]. Available: http://www.swfinstitute.org/sovereign-wealth-fund/. [Date of Access: 23 February 2017].

[25] IFSWF, «*What is the IFSWF?*» 2017. [Online]. Available: http://www.ifswf.org. [Date of Access: 22 Şubat 2017].

[26] M. Ercan, «*Türkiye küresel büyüme fonu-2*» 31 Ağustos 2013b. [Online]. Available: http://www.radikal.com.tr/yazarlar/metin-ercan/turkiye-kuresel-buyume-fonu-2-1148616/. [Date of Access: 12 Şubat 2017].

[27] O. Arolat, «*Dünyada Varlık Fonlarındaki Amaç Bugünün Zenginliğini Yarınlara Bırakmaktır Ya Bizimki...*» 8 Şubat 2017. [Online]. Available: http://www.dunya.com/kose-yazisi/dunyada-varlik-fonlarindaki-amac-bugunun-zenginligini-yarinlara-birakmaktir-ya-bizimki/349084. [Date of Access: 8 Şubat 2017].

[28] A. Arslan, «*Varlık Fonu Nasıl Denetlenecek?*» 8 Şubat 2017. [Online]. Available: http://www.dunya.com/kose-yazisi/varlik-fonu-nasil-denetlenecek/349078. [Date of Access: 8 Şubat 2017].

[29] R. Beck ve M. Fidora, «*The Impact of Sovereign Wealth Funds on Global Financial Markets*» July 2008. [Online]. Available: https://www.ecb.europa.eu/pub/pdf/scpops/ecbocp91.pdf. [Date of Access: 4 February 2017].

[30] T. Belli, «*Varlık Fonu'na Neden İhtiyaç Duyuldu?*» 9 Şubat 2017. [Online]. Available: http://www.dunya.com/kose-yazisi/varlik-fonuna-neden-ihtiyac-duyuldu/349233. [Date of Access: 9 Şubat 2017].

[31] M. Ercan, «*Türkiye küresel büyüme fonu*» 24 Ağustos 2013a. [Online]. Available: http://www.radikal.com.tr/yazarlar/metin-ercan/turkiye-kuresel-buyume-fonu-1147534/. [Date of Access: 11 Şubat 2017].

[32] M. Eğilmez, «*Kendime Yazılar: Varlık Fonu*» 25 Ağustos 2016. [Online]. Available: http://www.mahfiegilmez.com/2016/08/varlk-fonu.html. [Date of Access: 7 Şubat 2017].

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June2017, pp. 176~180
Available online at:http://pen.ius.edu.ba

Ecological Approaches in Textile Sector: The Effect of r-PET Blend Ratio on Ring Spun Yarn Tenacity

Esin Sarıoğlu
Gaziantep University, Faculty of Engineering, Textile Engineering Department,
27310 Şehitkamil/Gaziantep, Turkey

Article Info

Article history:

Received May 27th, 2017
Revised June 15th, 2017
Accepted June17th, 2017

Keyword:

Elongation
Recycling
Ring spinning
r-PET
Tenacity
Virgin PET

ABSTRACT

As the strategy of waste-management, it is very important to ensure that waste materials are recycled and reused in different industry in order to protect the ecological environment and there are so many initiatives related to this subject. Especially in the textile industry, recycling of PET bottle waste into recycled polyester fiber (r-PET) has made a difference in the industry to reduce load on environment pollution. In addition, it contributes to reducing the fossil fuels sources, water and energy which is the required amount in the production of synthetic polymers. With supporting these attempts, we have to fulfill our social responsibility in order to preserve the ecological balance. This study aims to compare the tenacity and elongation properties of ring spun yarns produced from r-PET fibers recycled from waste PET bottles and cotton fiber at different blend ratios. Besides, virgin PET fibers were also used to conduct the difference between recycled and virgin fibers. Both r-PET and virgin PET fibers were blended with cotton as 100%, 70%/30%, 50%/50% and 30%/70% ratios. All production parameters were constant to determine the effect of raw materials on yarn tenacity and elongation. Results showed that ring spun yarns containing r-PET fibers had lower tenacity and elongation than virgin PET. On the other hand, the quality parameters of r-PET fibers can be improved by technological developments, and so they will be preferred to preserve the ecological balance.

Corresponding Author:

Esin SARIOĞLU
Gaziantep University, Faculty of Engineering,
Textile Engineering Department, 27310
Şehitkamil/ Gaziantep, Turkey.
Email:sarioglu@gantep.edu.tr

1. Introduction

Nowadays, climate change has serious problem for all over the world. To overcome this problem some attempts have been performed by governments to minimize waste generation or reuse wastes. Polyethylene terephthalate (PET) bottles are produced from raw petrochemical products and waste after use has not affect environment directly. On the other hand, the increasing volume of PET bottle waste causes economical and environmental problems unless to be recycled [1]. But it is becoming critical problems, besides environmental and economic awareness, legislations has started to minimize the solid residues [2]. Meanwhile, recycling of post-consumer PET bottles has become a well-established system with its own logistic chain including bottles collection, flake production and pellet production [3]. Besides, recycling of PET bottles leads to decrease waste problem and use of raw petrochemical products, water and energy. Furthermore, it has been approximated that PET bottle recycling gives a benefit in greenhouse gas emissions of 1.5 tons of CO2 per tones of recycled PET [4]. On the other hand, recycling of PET bottles and using in textile industry give textile products an added value [5,6]. Recycling processes which can be mechanical or chemical are the best

way to reduce PET wastes into reused forms economically [7-10]. Furthermore, recycling process does not reduce cost but it is essential to conserve ecological balance.
PET bottles can be easily separated from other wastes, some additional processes are needed ie. breaking, washing, drying to obtain PET flakes. r-PET fibers to be used in textile industry are produced by melt spinning system from PET flakes. This recycled product can easily be adapted to textile product production instead of virgin PET. Approximately 60% of recycled PET polymer is used in the production of PET filament and staple fiber, this situation shows how important industry of textile [6]. Some researchers have focused on the usability and adaptability of r-PET fiber in textile industry [7,11-16].
This study aims to determine and compare the effect of using r-PET fiber with different blend ratio on ring spun yarn tenacity and elongation. At this respect, r-PET and virgin PET fibers (PET) were blended with cotton fiber at 100%, 70%/30%, 50%/50%, 30%/70% ratio, separately. Yarn samples were manufactured by ring spinning system and all production parameters were kept constant to evaluate the effect of blend ratio and raw material variables.

2. Materials and Methods

This study was achieved as cooperation with Gama Textile Company in Gaziantep/Turkey. r-PET fiber were produced by collecting, rating, washing and breaking, drying and reducing the size of PET bottles to obtain PET flakes. Then, PET flakes were converted into r-PET fiber by melt spinning process. The properties of r-PET fiber, virgin PET fiber and cotton fiber were given in Table 1. Fibers were weighted according to blend ratio and blended with sandwich blend method at the beginning of the blowroom. In the process order of the yarn production, carding, three passage drawframe, roving processes were carried out. 656 tex slivers were used and 19.7 tex yarns with α_e = 3.39 (730 TPM) twist level were produced as 100% r-PET, 100% virgin PET and cotton blends (70%/30%,50%/50% and 30%/70%) by ring spinning system at 13.500 rpm spindle speed. 100% cotton ring spun yarn was manufactured with α_e = 3.71 (800 TPM) twist level at the same spindle speed.

Table 1.Properties of raw materials

Properties	**Raw Material**		
	r-PET	**PET**	**Cotton**
Fineness, dtex	1.30	1.30	1.70*
Length, mm	38	32	31.98

*4.32 Micronaire (dtex cotton=Micronaire*0.394)

All yarn tests were carried out after conditioning the specimens in a standard atmosphere at 20±2 °C temperature and 65±4% relative humidity for 24 hours according to the standard of BS EN ISO 139:2005+A1:2011. Tenacity and elongation measurements of yarn samples were achieved with Uster® Tensorapid-4 according to BS EN ISO 2062:2009. Ten tests were performed in each 4 bobbins and reported values represent the average of those test results.
SPSS 22.0 package program at 95% confidence interval was used for multivariate analysis of variance (MANOVA) in order to determine the significance effect of raw material and blend ratio on yarn tenacity and elongation. Furthermore, Duncan's new multiple range test was provided in order to compare the difference between the means of treatment subgroups of blend ratios in analysis of variance was provided at significance level of 0.05.

3. Results and Discussion

In Figure 1, tenacity of yarn samples composed of PET/CO and r-PET/CO at different blend ratio is shown. It is obvious that yarns containing virgin PET fiber have higher tenacity than that of r-PET fiber. This decrease was expected because of the lower tenacity of r-PET fibers than PET fibers [13,16]. On the other hand, the increase in the synthetic blend ratio leads to higher tenacity of yarns both containing virgin PET and r-PET fibers. It is seen that, 50%/50% r-PET/CO blend yarn tenacity is lower as 1.81 cN/tex than 30%/70% r-PET/CO yarn tenacity.
Elongation at breaks histograms are illustrated in Figure 2. In all blend ratios of r-PET and PET fibers, it is seen that synthetic fibers contribute the elongation with respect to CO yarn. The results contributed with the

information already present in the literature [13,16]. It can be probably said that yarns produced with 100% r-PET yarn have highest result than 100% PET yarn.
MANOVA analysis of dependent variables (tenacity and elongation) between subjects is given in Table 2. Raw materials and blend ratio have a significant effect on breaking strength at $\alpha = 0.05$ confidence interval.

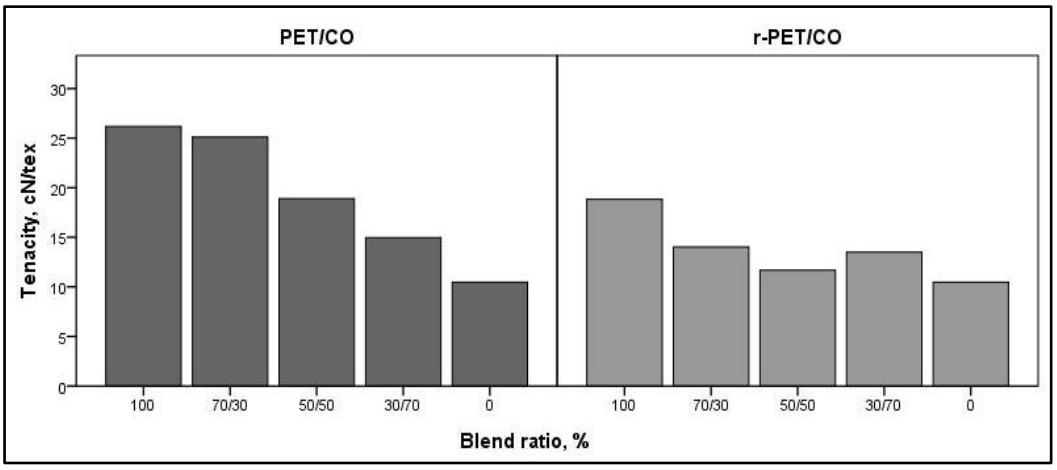


Figure 1. Tenacity of yarns

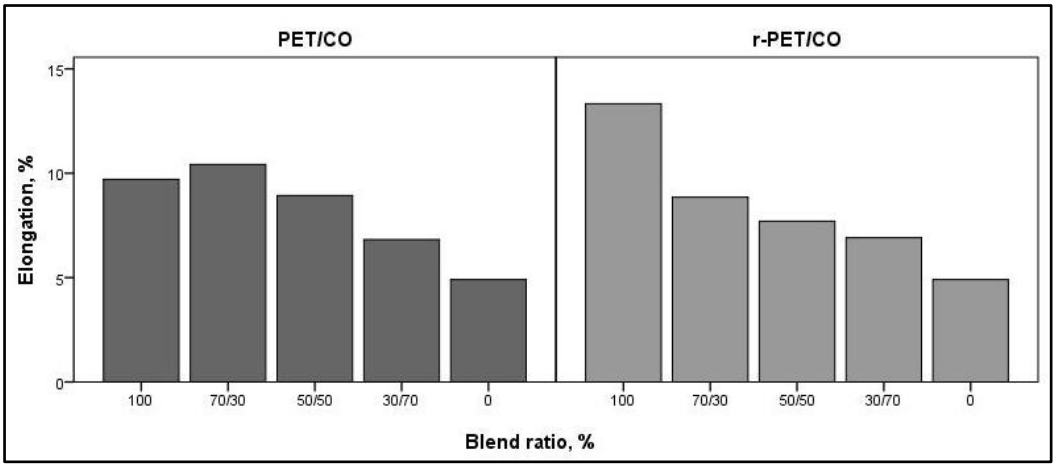


Figure 2. Elongation of yarns

The coefficient of variation (R^2) is a measurement of "goodness of fit" and ranges from "0" to "1".Analysis explains about 94.8 % of the variability in yarn tenacity for all yarn samples and it is evaluated as statistically significant for all independent variables ($p<0.05$). On the other hand, the effect of raw materials on yarn elongation is not found statistically important ($p=0.462$). It can be said that the elongation of r-PET and virgin PET blended yarns are close to each other and there is no difference statistically. Besides, blend ratio has statistically significant effect on yarn elongation. R^2 is determined as 93.1% with the high value.
From pair wise comparison of the mean tenacity, using Duncan tests, results at a significance level of 0.05 for blend ratio parameter trend is observed that the higher blend ratio of PET and r-PET raw materials (70%/30% and 100%)yarns has the higher tenacity than CO yarn which is represented as "0%" blend ratio (Table 3).It is clearly seen in Table 3, there is no significant difference between at 30%/70% and 50%/50% blend ratios ($p>0.05$). Table 4 illustrates Duncan's multivariate range test results of the mean elongation at a significance level of 0.05. The higher the PET or r-PET blend ratio the higher the elongation at break of ring spun yarn is obtained and also 100% CO yarn has the lowest elongation value.

Table 2. MANOVA results of between subject effects

Source	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Tenacity, cN/tex	1169.208[a]	9	129.912	60.561	.000
	Elongation, %	240.039[b]	9	26.671	45.271	.000

Intercept	Tenacity, cN/tex	10774.806	1	10774.806	5022.900	.000
	Elongation, %	2721.510	1	2721.510	4619.410	.000
Raw materials	Tenacity, cN/tex	294.415	1	294.415	137.248	.000
	Elongation, %	.328	1	.328	.556	.462
Blend ratio	Tenacity, cN/tex	706.663	4	176.666	82.356	.000
	Elongation, %	205.944	4	51.486	87.391	.000
Raw materials* Blend ratio	Tenacity, cN/tex	168.130	4	42.033	19.594	.000
	Elongation, %	33.767	4	8.442	14.329	.000
Error	Tenacity, cN/tex	64.354	30	2.145	-	-
	Elongation, %	17.674	30	.589	-	-
Total	Tenacity, cN/tex	12008.369	40	-	-	-
	Elongation, %	2979.223	40	-	-	-
Corrected Total	Tenacity, cN/tex	1233.563	39	-	-	-
	Elongation, %	257.713	39	-	-	-

a. R Squared = .948 (Adjusted R Squared = .932)
b. R Squared = .931 (Adjusted R Squared = .911)

Table 3. Effect of blend ratio on tenacity;based on means observed. Error term is the mean square (Error)=2.145. a.Uses harmonic mean sample size = 8.000, b. Alpha = 0.05

Duncan[a,b]					
Blend ratio	N	Subset			
		1	2	3	4
0%	8	10.48			
30%/70%	8		14.23		
50%/50%	8		15.29		
70%/30%	8			19.57	
100%	8				22.50
Sig.		1.000	.156	1.000	1.000

Table 4. Effect of blend ratio on elongation; based on means observed. Error term is the mean square (Error)=0.589. a.Uses harmonic mean sample size = 8.000, b. Alpha = 0.05

Duncan[a,b]						
Blend ratio	N	Subset				
		1	2	3	4	5
0%	8	4.9025				
30%/70%	8		6.8663			
50%/50%	8			8.3163		
70%/30%	8				9.6375	
100%	8					11.520
Sig.		1.000	1.000	1.000	1.000	1.000

4. Conclusion

This study was focused on the effect of raw materials and blend ratio of r-PET and PET containing CO ring spun yarn at finer count (Ne 30/1) on yarn tenacity and elongation. It was concluded that blend ratio has statistically significant effect on yarn tenacity and elongation. All these results showed that apparel containing r-PET fiber must be taken into consideration which has an alternative to virgin PET fiber in some aspect. It is not be denied that some attempts have been done by using r-PET fiber in order to contribute the ecological balance. The price of r-PET fiber is similar to virgin PET fiber because of the essential processes to degrade and recycle PET bottle. It is clear that despite the cost the consumption of ecologically friendly r-PET fiber seems to be seriously increased.

Acknowledgements

Author thanks Gama Textile Company for r-PET fiber supplying from their recycling company and contribution for yarn samples production of this study. The author also thanks Karacasu Textile Company, who supplied virgin polyester fiber.

References

[1] L. Bartolome, M. Imran, B.G. Cho, W.A. Al-Masry and D.H. Kim, "Recent developments in the chemical recycling of PET," Material Recycling - Trends and Perspectives, InTech publisher, pp.65-84, 2012.

[2] R.A. Sanches, K. Takamune, B. Guimaraes, R. Alonso, J.Baruque-Ramos, M.S. Barros de Held and J.P.P. Marcicano, "Wearability analysis of knitted fabrics produced with colored organic cotton, bamboo rayon, corn, recycled pet/cotton and recycled pet/polyester," *American International Journal of Contemporary Research*, vol.4, issue.4, pp.29-37, April 2014.

[3] L. Shen, E. Worrell and M.K. Patel, "Open-loop recycling: A LCA case study of PET bottle-to-fibre recycling," *Resources, Conservation and Recycling,* vol.55, pp.34-52, 2010.

[4] J. Hopewell, R. Dvorak and E. Kosior, "Plastics recycling: challenges and opportunities," *Phil.Trans.R.Soc.B,* issue.364, pp.2115-2126, 2009.

[5] F. Awaja and D. Pavel, "Recycling of PET," *European Polymer Journal*, vol.41, pp.1453-1477, 2005.

[6] A. Telli, N. Özdil and O. Babaarslan, "Usage of PET bottle wastes in textile industry and contribution to sustainability, *Journal of Textiles and Engineer,* vol.19, issue.86, pp.49-55, 2012.

[7] R.A. Sanches, K. Takamune, B.M. Guimaraes, R.S. Alonso, D. Karam Jr, J.P.P. Marcicano, A.Y. Sato Duarte, F.G. Dedini, "Comparative study of characteristics of knitted fabrics produced from recycled fibres employing the chauvenet criterion, factorial design and statistical analysis,". *Fibres & Textiles in Eastern Europe,* vol.23, issue. 4(112), pp.19-24, 2015.

[8] J.C. Tapia-Picazo, J.G. Luna-Barcenas, A. Garcia-Chavez, R. Gonzales-Nunez, A. Bonilla-Petriciolet and A. Alvarez-Castillo, "Polyester fiber production using virgin and recycled PET," *Fibers and Polymers*, vol.15, issue.3, pp.547-552, 2014.

[9] A.E. Tayyar and S. Üstün, "Usage of recycled PET," *Pamukkale University Engineering Science Journal,* vol.16, issue.1, pp.53-62, 2010.

[10] I.A. Ignatyev, W. Thielemans and B.V. Beke, "Recycling of polymers: a review," *ChemSusChem,* vol.7, pp.1579-1593, 2014.

[11] A.Telli and N. Özdil, "Effect of recycled PET fibers on the performance properties of knitted fabrics," *Journal of Engineered Fibers and Fabrics,* vol.10, issue.2, pp.47-60, 2015.

[12] R. Atakan, "Use of recycled poly (ethylene terephtalate) fibers in needlepunched automotive carpets," *Istanbul Technical University, Institute of science and Technology, Department of Textile Engineering,* M.Sc. Thesis, pages. 91, 2014.

[13] M.E. Yüksekkaya, G. Celep, G. Doğan, M. Tercan and B. Urhan, "A comparative study of physical properties of yarns and fabrics produced from virgin and recycled fibers" *Journal of Engineered Fibers and Fabrics,* vol.11, issue.2, pp.68-76, 2016.

[14] I.Mari and Y. Shinji, "Performance and durability of woven fabrics including recycled polyester fibers," *Journal of Textile Engineering,* vol.50, issue.2, pp.25-30, 2004.

[15] S. Rajamanickam and K. Vasudevan, "Study of antibacterial activity of chitosan on lyocell and recycled polyester yarns," *International Journal of Innovative Research in Science, Engineering and Technology,* vol.3, issue.2, pp.9480-9486, February 2014.

[16] A. Telli and N. Özdil, "Properties of the yarns produced from r-pet fibers and their blends," *Tekstil ve Konfeksiyon,* vol.23, issue.1, 2012.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 181~186
Available online at: http://pen.ius.edu.ba

Compression Properties of Woven Carpet Performance under Dynamic Loading

Deniz Vuruşkan[1], Esin Sarıoğlu[2], Halil İbrahim Çelik[2],Hatice Kübra Kaynak[2]
[1]Gaziantep University, Faculty of Fine Arts, Department of Fashion and Textile Design
[2]Gaziantep University, Faculty of Engineering, Textile Engineering Department

Article Info

Article history:

ReceivedMay27th, 2017
Revised June15th, 2017
Accepted June 17th, 2017

Keyword:

Acrylic
Dynamic loading
Wilton woven carpet
Pile height
Pile denisty

ABSTRACT

Although carpets are seen as decorative products for consumers, it is important that they must have optimum quality performance. The most important features affecting quality performance are pile fiber, pile yarn, pile height, pile density, carpet surface structure (cut pile or loop pile), carpet construction etc. During usage the carpet are exposed to a number of forces due to compressional loading such as dynamic or static. To counteract these forces, the resilience of pile yarn is vital. This paper demonstrates the influence of pile density and pile height of structure parameters on compression performance which was exposed to dynamic loading. In that respect, acrylic fiber was used as pile to manufacture Wilton face-to-face cut-pile carpets at two pile densities (2400 piles/dm^2, 2880 piles/dm^2) and three pile heights (7 mm, 11 mm and 16 mm). To determine the compression properties, carpets were subjected to dynamic loading at 50, 100, 200 and 1000 impacts. Thickness of carpets was taken at each of these four impacts. Finally, thickness loss of carpets as well as compression performance was detected. In order to identify the effect of pile density, pile height and number of impact on thickness loss of carpet after dynamic loading, analysis of variance was performed statistically. Results showed that pile height, pile density and number of impact have statistically significance on compression performance of carpet samples.

Corresponding Author:

Esin SARIOĞLU
Gaziantep University, Faculty of Engineering,
Textile Engineering Department, 27310
Şehitkamil/ Gaziantep, Turkey.
Email:sarioglu@gantep.edu.tr

1. Introduction

Carpet is predominantly used in home floor covering as an indispensable decorative product and also preferred by its heat and sound insulation feature. Compression performance in general terms of mechanical properties influences carpet performance under dynamic or static loads. Carpet thickness will be deformed when it is exposed to dynamic and static loads which are created by walking and furniture, respectively. During daily usage of the carpet, thickness loss is directly affected by raw material, pile height, carpet construction, pile density etc. There are a lot of studies focused on effects of these parameters on carpet performance based on static loading, dynamic loading and compressibility [1-15]. Javidpanah *et al.* studied cut-pile carpets made of heat process modified polyester pile yarn thickness loss of cut-pile carpets after dynamic loading. Four different 1800 denier and 96 filament in the cross section of air textured polyester pile yarns; normal, frieze, heat set and twist heat set were used as pile yarn. In order to analyze the carpet compression performance 50, 100, 200, 500, 1000 and 2000 dynamic impacts were acted on carpet samples. It was stated that physical and mechanical properties of air textured polyester pile yarns do not havesignificant changes after heat processing [4]. Çelik and Koç investigated on some selected carpet samples made of wool,

acrylic and polypropylene pile yarns to evaluate the performance of carpets under dynamic loading. In this study, carpets were exposed 50, 100, 200, 500 and 1000 dynamic impacts and then thickness losses were analyzed. They put forward that an increase in the number of impacts increase the thickness loss. It was found that acrylic fiber carpet had highest recovery capability than wool and polypropylene fiber carpets [13]. Çelik determined the effect of acrylic fineness, 2.75 denier, 6 denier and 8 denier, on carpet performance. Among the all analyses in order to identify carpet performance, dynamic loading tests were performed under 50, 100, 200, 1000 and 2000 impacts. It was resulted that acrylic fiber fineness had significant effect on thickness loss of carpet samples. The highest thickness loss was detected at carpet sample produced from acrylic pile yarn with 2.75 denier fiber fineness [8].

The aim of this study is to investigate the influences of pile height and pile density on woven carpet compression performance under dynamic loading with 50, 100, 200 and 1000 impacts. To determine the relationships between independent variable (pile height, pile density and number of impact) and response variable (thickness loss) multivariate variance analysis (MANOVA) was performed by SPSS package program.

2. Materials and Methods

Six acrylic cut-pile carpets were manufactured by Wilton face-to-face carpet weaving machine with three rapiers which enables three weft shots. The structure for all carpets was chosen as 2/3V weave construction which is illustrated in Figure 1.

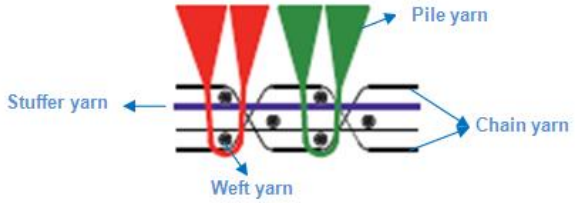


Figure 1. 2/3 V weave construction [16,17]

Acrylic fiber was used as pile with 5.6 denier linear density. All carpet production parameters were kept constant such as machine speed, weft and warp yarns used,construction. Carpet compositions are shown in Table 1. Carpet specifications are given in Table 2 with respect to pile height and pile density variables.

Table 1. Carpet samples composition

	Pile yarn	Warp yarn		Weft
		Stuffer yarn	Chain yarn	
Material	Acylic	80% Polyester/ 20% Cotton	Polyester	Jute
Yarn linear density, tex	200	197	89	491

Table 2. Carpet specifications

Warp density (ends/dm)	Weft density (picks/dm)	Pile Density (piles/dm^2)	Pile Height (mm)	Pile Weight (g/m^2)	Carpet Weight (g/m^2)
48	50	2400	7	918.549	1929.882
48	60	2880	7	1205.600	2413.000
48	50	2400	11	1374.654	2476.000
48	60	2880	11	1611.245	2846.064
48	50	2400	16	1980.400	3071.200
48	60	2880	16	2431.240	3728.400

All carpet specimens were conditioned with 65±4 % relative humidity and 20±2 ^{o}C temperature according to ISO 139:2005 [18]. Five test specimens were prepared as 125mm*125mm dimensions for each carpet. In order to perform dynamic loading test WIRA dynamic loading machine which drops free falling weight on carpet specimen at every five seconds was used. Carpet specimen was clamped on to a steel plate that is slowly and continuously traversed in such a way that there is 3.2 mm movement between each drop of the weight at each impact. Tests were conducted according BS ISO 2094:1999 [8,19,20]. Before applying dynamic loading all carpet thickness were measured in accordance with ISO 1765:1986 with WIRA digital thickness gauge under standard pressure of 2 ±0.2 kPa and this process repeated after 50, 100, 200 and 1000 impacts immediately [21]. Thickness loss in percentage was determined as a difference between the thickness at zero impact and at each stage of impact by using Equation (1).

$$Thickness\ loss, \% = \frac{h_0 - h_c}{h_o} x100 \quad (1)$$

where: h_0 is initial thickness and h_c is thickness after dynamic loading at each stage of impacts.
For statistical analysis SPSS package program was used to assess the effect size and significance of pile height, pile density and number of impact on thickness loss of carpet for each stage of impact at 95% confidence interval.

3. Results and Discussion

Thickness losses in percentage of acyclic carpets with different pile densities and pile heights after 50, 100, 200 and 1000 impacts are shown in Figure 2.
Thickness loss of acrylic cut-pile carpets increases from 50 to 1000 impacts with the increase in number of impact. Performance of carpets at 7 mm pile height for each pile density against compression is higher than that of 11 mm and 16 mm carpets. In addition, it is clearly seen that increase in pile density contributes to the compression performance of carpets with 11 mm and 16 mm pile heights. This situation can be explained with having more pile yarns within the unit area results higher resistance against dynamic load impacts. On the other hand, the same situation is not directly observed for carpets with 7 mm pile height. Thickness loss difference between 2400 piles/dm^2 is lower 3% than that of 2880 piles/dm^2 for 100 impacts.

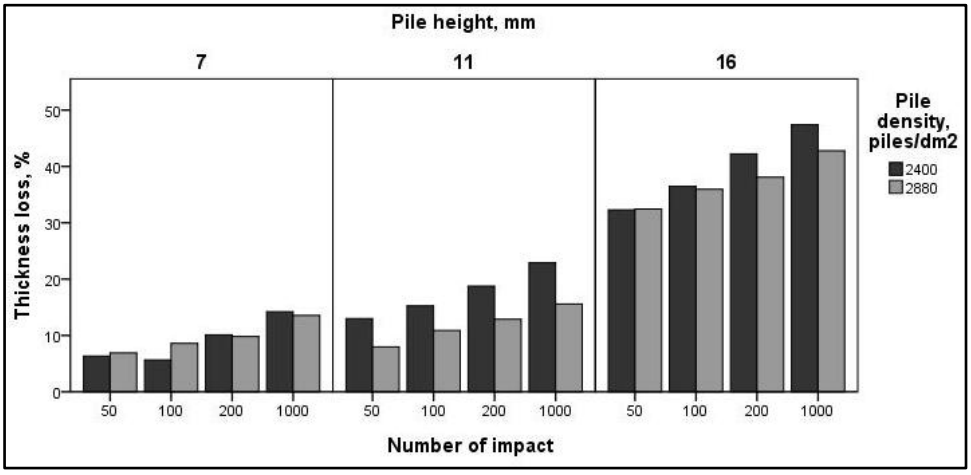


Figure 2. Thickness loss of cut-pile carpet samples versus to number of impact

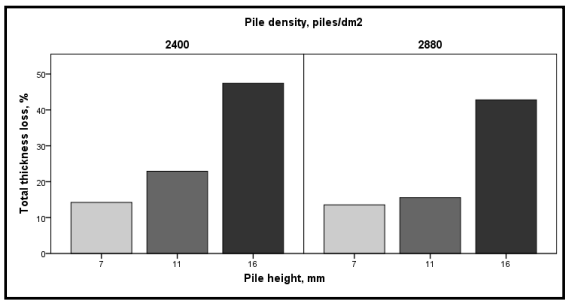


Figure 3. Total thickness loss of cut-pile acrylic carpet samples

Total thickness loss in percent of cut-pile acrylic carpet samples with different pile density and pile height is shown in Figure 3. When constant pile height is taken into consideration, the difference of thickness loss in percent for 2400 piles/dm^2 carpet has the higher value of 4.7% than 2880 piles/dm^2. This result is similar for 11 mm and 16 mm cut-pile carpets with the thickness loss value of 32% and 9.7%, respectively. In conclusion, the influence of pile density on thickness loss is clearly stated that the higher the pile density, the lower the thickness loss after dynamic loading at 1000 impacts.

MANOVA results for thickness loss after dynamic loading for independent variables are seen in Table 3. When the effect of pile height, pile density and number of impact on thickness loss is examined, thickness loss values are seen as statistically significant (R^2= 96.6 %).

In order to evaluate the effects of subgroups for number of impact and pile height (pile density was not considered because of lower than three subgroups), Duncan's multivariate range tests were achieved and results are illustrated in Table 4 and Table 5, respectively. In Table 4, increase in number of impacts affects the carpet thickness loss negatively. Furthermore, carpets with higher pile height have lower resistance to dynamic loading with higher thickness loss (Table 5).

Table 3. MANOVA for thickness loss under dynamic loading

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17024.242[a]	23	740.184	88.220	.000
Intercept	41680.710	1	41680.710	4967.758	.000
Number of impact	1242.777	3	414.259	49.374	.000
Pile height, mm	15343.407	2	7671.704	914.360	.000
Pile density, piles/dm^2	142.241	1	142.241	16.953	.000
Number of impact * Pile height	75.874	6	12.646	1.507	.188
Number of impact * Pile density	50.026	3	16.675	1.987	.123
Pile height* Pile density	158.538	2	79.269	9.448	.000
Number of impact * Pile height * Pile density	11.381	6	1.897	.226	.967
Error	604.098	72	8.390		
Total	59309.050	96			
Corrected Total	17628.340	95			

a. R Squared =.966 (Adjusted R Squared = .955)

Table 4. Duncan's multivariate range test results according to number of impacts

		Duncan[a,b]			
		Subset			
Number of impact	N	1	2	3	4
50	24	16.4952			
100	24		18.7959		
200	24			21.9790	
1000	24				26.0773
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square(Error) = 8.390.

a. Uses Harmonic Mean Sample Size = 24.000.

b. Alpha = 0.05.

Table 5. Duncan's multivariate range test results according to pile heights

Duncan[a,b]				
		Subset		
Pile height, mm	N	1	2	3
7	32	9.4018		
11	32		14.6518	
16	32			38.4569
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. Based on observed means.
The error term is Mean Square(Error) = 8.390.
a. Uses Harmonic Mean Sample Size = 32,000.
b. Alpha = 0.05.

4. Conclusion

In order to assess the influence of pile density and pile height on thickness loss of carpet exposed to dynamic loading at different impacts, acrylic cut-pile carpets were used in this study. It is expected and desired that the carpets should have the highest performance under the dynamic loading which simulate the traffic wear during the usage. In accordance with the statistical analysis, both the pile density and pile height parameters have significant effect on dynamic loading performance of the carpet samples. As a conclusion to the test results, it can be said that the lowest thickness loss was obtained with the carpet sample at 7 mm pile height and 2880 piles/dm^2 pile density. Since performance of carpets at 7 mm pile height for each pile density against compression is higher than that of 11 mm and 16 mm carpets, it can be resulted that lower pile heights provide better dynamic loading performance. It is also clearly seen that increase in pile density contributes to the compression performance of carpets with 11 mm and 16 mm pile heights.

References

[1] Y. Korkmaz and S. Dalcı Kocer, "Resilience behaviors of woven acrylic carpets under short- and long-term static loading," *The Journal of the Textile Institute*, vol.101, issue 3, pp. 236-241, 2010.
[2] E. Koç, N. Çelik and M. Tekin, "An experimental study on thickness loss of Wilton-type carpets produced with different pile materials after prolonged heavy static loading: Part 1: Characteristic parameters and carpet behavior," *Fibres & Textiles in Eastern Europe*, vol. 13, issue 52, pp. 56–62, 2005.
[3] N. Çelik and E. Koç, "An experimental study on thickness loss of Wilton type carpets produced with different pile materials after prolonged heavy static loading. Part 2: energy absorption and hysteresis effect," *Fibres & Textiles in Eastern Europe*, vol.15, issue 3(62), pp. 87-92, 2007.
[4] M. Javidpanah, N.S. Shaikhzadeh and M. Dayiary, "Study on thickness loss of cut-pile carpet produced with heat process-modified polyester pile yarn. Part I: static loading," *The Journal of the Textile Institute*, vol. 105, issue 12, pp. 1265-1271, 2014.
[5] S.M. Ishtiaque, K. Sen and A. Kumar, "Influence of yarn structures; part A: on carpet compressional performance under static and dynamic conditions," *The Journal of The Textile Institute*, vol. 106, issue 11, pp. 1190-1202, 2014.
[6] S.A. Mirjalili and M. Sharzehee, "An investigation on the effect of static and dynamic loading on the physical characteristics of handmade Persian carpets: Part I – the effect of static loading," *The Journal of The Textile Institute*, vol.96, issue 5, pp.287-293, 2005.
[7] H. Sheikhi, N.S. Shaikhzadeh, S.M. Etrati and M.D. Bidgoly, "Effect of the acrylic fibre blend ratio on carpet pile yarn compression behavior," *Fibres & Textiles in Eastern Europe*, vol. 20, issue 4(93), pp.77-81, 2012.
[8] H.İ. Çelik, "Effects of fiber linear density on acrylic carpet performance," *Journal of Engineered Fibers and Fabrics,* vol.12, issue (1), pp.1-11, 2017.
[9] M. Dayiary, N.S. Shaikhzadeh, M. Shamsi , "An experimental verification of cut-pile carpet compression behavior," *The Journal of The Textile Institute*, vol.101, issue 6, pp. 488-494,2010.

[10] N. Özdil, F. Bozdoğan, G. Özçelik Kayseri and G. Süpüren Mengü, "Compressibility and thickness recovery characteristics of carpets," *Tekstil ve Konfeksiyon*, 3/2012, pp. 203-2011, 2014.
[11] Ü.H. Erdoğan, "Effect of pile fiber cross section shape on compression properties of polypropylene carpets," *The Journal of The Textile Institute*, vol.103, issue 12, pp. 1369-1375, 2012.
[12] M. Javidpanah, N.S. Shaikhzadeh and M. Dayiary, "Study on thickness loss of cut-pile carpet produced with heat process modified polyester pile yarn. Part II: dynamic loading," *The Journal of the Textile Institute*, vol. 106, issue 3, pp. 236-241, 2015.
[13] N. Celik and E. Koc, "Study on the thickness loss of Wilton-type carpets under dynamic loading," *Fibres & Textiles in Eastern Europe*, vol.18, issue 1(78), pp. 54-59, 2010.
[14] K. Dubinskaite, L.V. Langenhove and R. Milasius, "Influence of pile height and density on the end-use properties of carpets," *Fibres & Textiles in Eastern Europe*, vol.16, issue 3(68), pp. 47-50, 2008.
[15] N. Çelik, H.K. Kaynak and Z. Değirmenci, "Performance properties of Wilton type carpets with relief texture effect produced using shrinkable, high bulk and relaxed acrylic pile yarns," *Association of Textile, Apparel and Material Professionals*, pp. 43-47, September 2009.
[16] Van De Wiele carpets weave structure catalogue.
[17] D. Vuruşkan, "Carpet fiber mobility due to traffic wear," *Industria Textila* (Accepted for publishing).
[18] ISO 139:2005-Textiles. Standard atmospheres for conditioning and testing.
[19] http://www.wira.com/media/other/37656/WiraDynamicLoading.pdf (Available on 18.02.2017).
[20] BS ISO 2094:1999 Textile floor coverings. Determination of thickness loss under dynamic loading.
[21] ISO 1765:1986 Machine-made textile floor coverings. Determination of thickness.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 187~193
Available online at:http://pen.ius.edu.ba

Determination of Pozzolanic Activity for Using Natural Zeolite Analcime in Sustainability Additive Cement Products

Yasemin AKGÜN
Department of Renewable Energy, Ordu University, Ordu, Turkey

Article Info

Article history:

Received May29th, 2017
Revised June15th, 2017
Accepted June 17th, 2017

Keyword:

Analcime
Clinoptilolite
Pozzolanic activity
Zeolite

ABSTRACT

It is known that the cement industry is responsible for 5-8% of world CO_2 emissions and also for intensive energy consumption. For this reason, cement productions need to sustainability studies. Mineral admixtures added to cement as partial replacement material enable to sustainable blended cement productions due to used less amount of cement. Mineral admixtures with pozzolanic property are also preferred in terms of increasing cement performances. This situation corresponds to improved performance of cement and concrete products as well as saving energy, reducing world CO_2 emissions. In recent years, the cement industry has been using natural zeolites extensively as pozzolanic materials. Analcime is known as second valuable zeolite mineral after from clinoptilolite in natural zeolite groups The aim of this study is to determinate the pozzolanic properties of analcime and to investigate whether it has potential availability in sustainable blended cement production. The clinoptilolite was used with comparison purpose in this study. Blaine values, densities, chemical composions, pozzolanic activities, mineralogical structures of analcime and clinoptilolite which are subject of study were determined. Accordance with TS 25, which contains pozzolan conformity criterias, 7-days average compressive strength values of lime-pozzolan mixture samples were determined. The datas obtained shown that, the 7-days average compressive strengths of lime-zeolite (pozzolan) blended samples are 9.02 MPa for clinoptilolite and 6.3 MPa for analcime. The total content of $Si0_2$ + Al_2O_3 + Fe_2O_3 was 77.3% for clinoptilolite and 73.16% for analcime. Accordingly, analcime which is a natural zeolite satisfies to puzolan conformity criterias in TS 25 has the potential to be an alternative to clinoptilolite which is more widely used in cement productions.

Corresponding Author:

Yasemin Akgün,
Departement of Renewable Energy,
Ordu University,
Ordu, Turkey
Email: yakgun@odu.edu.tr

1. Introduction

Cement is a construction material that needs to sustainability studies due to the decrease of non-renewable energy resources and the increase of CO2 emissions in the world. The easiest solution in sustainability studies is to produce blended cement by using pozzolans. Nowadays, the use of pozzolans which are substituted by cement has become very popular. The use of portland cement in a lesser amount leads to less energy consumption and less CO2 emissions. Thus, more environmentalist, energy saving, economical and sustainable cement productions can be possible. Also, the pozzolans with high activity affect positively to performances of mortar/concrete.
Pozzolans are defined as materials with silica and alumina. They have either any or very low binding property on their own. But, in the fine grained state, they are capable of exhibiting hydraulic binding when combined

with calcium hydroxide in hydrous medium. Pozzolanic activity is defined as how much can provide reacting with slaked lime and water of pozzolanic materials and how much binding it can provide [1].
In other words, pozzolanic activity can be defined as the ability to react with Ca(OH)2 of active silica which is in the pozzolan. At the end of this reaction the amount of portlandite (Ca(OH)2) is reduced, calcium silicate hydrate (CSH) is increased [2]. To determine the pozzolanic activity, various chemical and mechanical experiments were included in the standards [3,4,5]. With chemical experiments, silica and Ca(OH)2 are determined qualitatively and quantitatively. In mechanical experiments, it is determined whether pozzolans have active silica by determining flexural and compressive strengths of mortars produced with pozzolans mixed with lime or cement [6].
It is known that, zeolites have used as pozzolanic additives in mortar and concrete productions. The natural zeolites formed by the alteration of the vitric pyroclastic deposits are more reactive materials than the fly ash and furnace slags between mineral additives [7]. Zeolites contribute to the formation of cement-like hydrated products during the hydration of cement and to Ca(OH)2 consumption occurred during the hydration process. So, zeolites improve performances of mortar/concrete [8]. Analcime is known as second valuable zeolite mineral after from clinoptilolite in natural zeolite groups. Analcime is a feldspathite mineral with a very large amount of hydrated sodium aluminosilicate (Na (AlSi2O6) .H2O) in its structure. The clinoptilolite is a natural zeolitic mineral species with chemical formula (Na3K3) (Al6Si30O72) 24H2O, which is rich in silica and contains alkali and earth alkaline cations [9].
Despite the large number of studies on pozzolanic activity of clinoptilolite in the literature, studies on that of analcime are very limited [10,11]. This study has been carried out in order to provide actively using of local and natural resources that could contribute to the sustainability of cement. The use of such natural additives with optimum values may be possible with scientific research outputs. So, the aim of this study is to determinate the puzolanic properties of analcime and to investigate whether it has potential availability in sustainable blended cement production. The clinoptilolite was used with comparison purpose in this study.

2. Materials and Methods

2.1. Materials

In experimental studies, the clinoptilolite and analcime which are natural zeolite minerals were used as replaced material by cement. The analcime and clinoptilolite were obtained from Ordu/Perşembe and Manisa/Gördes regions in Turkey, respectively. The two different natural zeolite samples were obtained by grinding from zeolite rocks in a ball mill. As a fineness parameter, in accordance with ASTM C430 [12] material percentage passing from 45-μm was used. In pozzolanic activity tests, CEN standard sand which has preferably round granulated and characterized by a natural silica sand content of at least 98% silica dioxide according to TS EN 196-1 [13] standard was used. In lime-pozzolan mixtures, slaked lime (Ca(OH)2) as specified in TS 25 [5] was used. In the production of the samples, water which does not contain organic matter and mineral salts which may be harmful were used.

2.2. Methods

The specific surface, density, chemical composition, mineralogical structure of the materials used as pozzolan have an important effect on pozzolanic activity. The following methods were used for the determination of these parameters effected on pozzolanic activity of natural zeolites used in the study. Additionally, the determination method of pozzolanic activities of natural zeolites was mechanical experiment method which is determined by average compressive strengths of lime-pozzolan mortars.
Firstly, the physical properties of the natural zeolites were determined. The densities were determined according to TS EN 197-1 [14]. The specific surface(Blaine) were determined according to TS EN 196-6 [15]. X-Ray Diffraction (XRD) Analysis was performed to determine the chemical composition of natural zeolites. SEM views were also obtained using a Scanning Electron Microscope. The mineralogical structures of natural zeolites were determined by using XRD analysis. And then, the pozzolanic activities of natural zeolites were determined according to TS 25.

2.3. Preparation of the Samples and Tests on Pozzolanic Activity

In TS 25, the pozzolanic activity test is defined as a characteristic determined in terms compressive strength of the mortar obtained by mixing natural pozzolan which is grinded at a certain fineness with water, standard

sand and calcium hydroxide ($CaOH_2$). The amounts of materials required to prepare three test samples for tests on pozzolanic activity are given in Table 1.

Table 1. The amounts of materials for tests on pozzolanic activity

		The amounts for tests	
	TS 25	Clinoptilolite	Analcime
Slaked lime ($CaOH_2$)	150gr	150gr	150gr
Pozzolan	2x150x (pozzolan density /$CaOH_2$density)	2x150x(2.11/2.15)= 294.42gr	2x150x(2.28/2.15) =318.14gr
Standard sand	1350gr	1350gr	1350gr
Water	0.5x(150+ pozzolan)	0.5x(150+294.42) =222.21gr	0.5x(150+318.14) =234.07gr

The moulds of the prepared samples were covered with a glass plate to prevent evaporation. The samples were allowed to stand at room temperature for 24 hours (23 ± 2) ° C. And then, they were left for 6 days in an drying oven at 55 ± 2 ° C without removing the moulds. The samples removed from the oven were left to cool until the room temperature reached. Finally, the compressive strengths of samples were performed in accordance with TS EN 196-1.

3. Results and Discussions

3.1. The Physical Properties, Chemical Compositions and Pozzolanic Activities of Zeolites

The physical properties, chemical compositions and pozzolanic activity values of natural zeolites are given Table 2. XRD diffraction patterns of zeolitesare given Figure 1 and Figure 2.

Table 2. The physical properties, chemical compositions and pozzolanic activity values of natural zeolites (Cli. denotes clinoptilolite and Anl. denotes analcime)

Chemical content	Cli. (wt.%)	Anl. (wt.%)	Physical properties		
SiO_2	64.70	46.71		Cli	Anl.
Al_2O_3	11.21	17.24	Density (g/cm^3)	2.11	2.28
Fe_2O_3	1.38	9.21	Specific surface (cm^2/g)	4079	4780
CaO	2.08	3.03	Pozzolanic activity values		
MgO	0.79	5.29	TS 25 limit values	C	A
Na_2O	0.38	4.84	Lime-pozzolan mix.7daycomp. strength >4MPa	9.02	6.30
K_2O	3.78	4.08	SiO_2+Al_2O_3 +Fe_2O_3	77.30	73.16
Loss of ignition	11.80	7.00	wt.content >%70		

In TS 25, one of the conformity criterias for pozzolans is the 7 day compressive strength of samples prepared with lime-natural pozzolan mixture. The limit value of the compressive strength is at least 4 MPa.In experimental studies performed for clinoptilolite and analcime, the average compressive strength values for the lime-zeolite (pozzolan) mixture samples were determined as 9.02MPa and 6.30MPa, respectively.It has also been emphasized that the sum of SiO_2 + Al2O_3 + Fe_2O_3 in TS 25 should be at least 70% by mass.The value of this total was found to be 77.3% for clinoptilolite and 73.16% for analcime.At the same time, the specific surfaces of the pozzolans should be greater than 3000 cm^2/gr. The specific surfaces of the pozzolans which is used in this study were found to be 4079 cm^2/gr for clinoptilolite and 4780 cm^2/gr for analcime. In

the pozzolanic activity tests. Because of the specific surfaces of natural zeolites were below of portland cement fineness, the reaction which is between pozzolan and lime was increased. It is thought that, this situation was lead to an increment at the value of pozzolanic activity.These values show that the zeolites used in the study have an usability potential as a pozzolan.

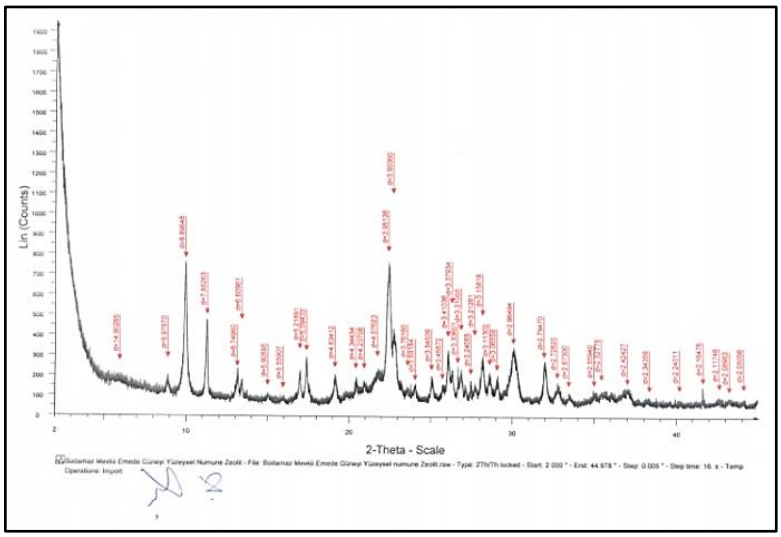


Figure 1.XRD diffraction patterns of clinoptilolite

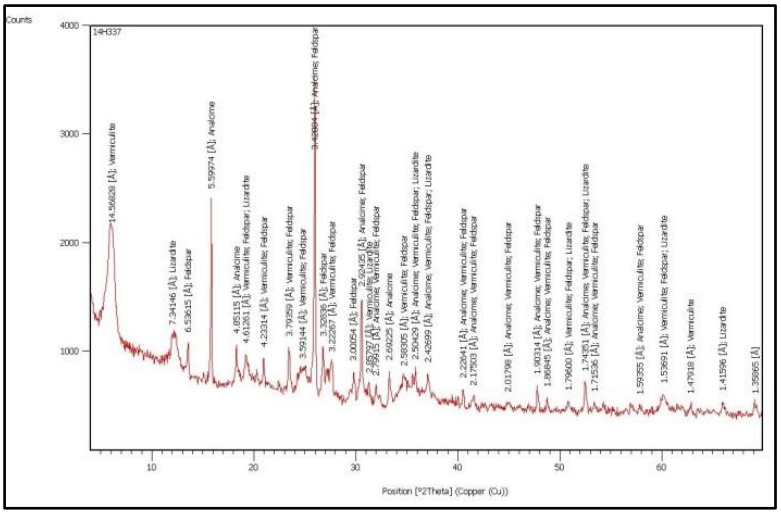


Figure 2.XRD diffraction patterns of analcime

3.2. Mineralogical Structures of Zeolites

According to the mineral modal ratios at the mineralogical composition results determined by the X-ray diffraction analysis (XRD) of the clinoptilolite sample, the sample is characterized by zeolite industrial raw material. The modal-mineralogical composition identified as the result of the XRD analysis of the sample is given below. The ratio of clinoptilolite in the sample is 80-85% (Figure 3). As other minerals; Opal-CT is in a certain ratio, illite mica, quartz and feldspat are low ratios.SEM views obtained using a Scanning Electron Microscope of clinoptilolite were determined with analysis result reports performed by Gördes Zeolite Company.

- ✓ Clinoptilolite (Silicate–Zeolite Group Mineral) (%80-85)
- ✓ Opal-CT (Opal-Critobalite/Tridimite) (Silicate-Silica Group Mineral) (10-15%)
- ✓ Quartz (Silicate-Silica Group Mineral (% <2)
- ✓ Feldspat (Na and K-Felspat) (Silicate-Feldspat Group Mineral) (% <2)
- ✓ İllit-Mica (Silicate-Clay-Mica Group Mineral) (% <5)

The analcime rock is a vitric tuff and consists of glass splinters and crystal components. The glass splinters are converted to zeolite and chlorite, which are heavily altered. Cryptocrystalline silica formations are present in the binder material. The crystalline components are heavily fragmented augite (pyroxene) and very little biotite. Opaque minerals are found in less than 5% of the rock (Figure 4).

SEM views of analcime were determined by Mineralogy and Petrography Laboratory of General Directorate Of Mineral Research And Explorations. The clinoptilolite and analcime samples confirm the national and international standards required for zeolite applications.

Figure 3. SEM view of clinoptilolite sample

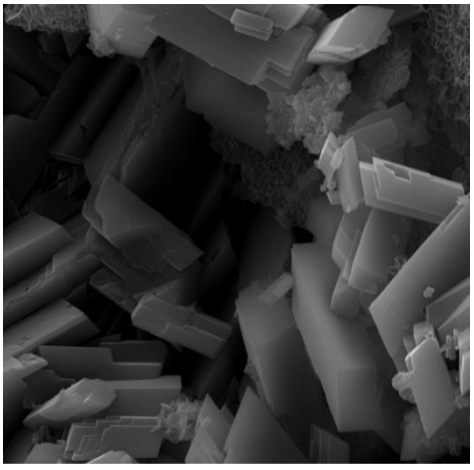


Figure 4. SEM view of analcime sample

When the SEM views of the two zeolites are examined, it is understood that the clinoptilolite and analcime zeolites are in a crystal structure. It is thought that, despite crystal structures of natural zeolites, the reason of exhibit pozzolanic activity is the may be reaction with Ca (OH) 2 of free silica and alumina components as a result of dissolution at certain scale of the crystal structure in high pH environment. There are some studies in the literature about the dissolution of crystalline structures in low or high pH environments of natural zeolites [16,17].

4. Conclusions

1) It has been determined that both natural zeolites (clinoptilolite and analcime) used in the study have potential to be used in sustainable blended cement productions. Due to their favorable qualities such as silica-alumina contents, pozzolanic activity values, low densities, high specific surfaces, glassy structures of rocks and mineralogical structures.
2) The 7-days average compressive strength values of lime-pozzolan mixtures for clinoptilolite and analcime determined by pozzolanic activity tests accordance with TS 25 were 9.02 MPa and 6.30 MPa respectively. Accordingly, the determined compressive strengths are satisfied by TS 25 limit values.

3) The total SiO_2, Al_2O_3 and Fe_2O_3 contents of the natural zeolites used in the study are similar to some pozzolanic materials used in the cement industry.The value of this total was found to be 77.3% for clinoptilolite and 73.16% for analcime. The determined total content values are satisfied by TS 25 limit values.

4) In the result of this study conducted to determinate the puzolanic activity of analcime and to investigate whether it has potential availability in sustainable blended cement production. It is thought that analcime which is the second valuable mineral of natural zeolites may be an alternative to clinoptilolite, which is more widely used in the construction industry. It is also thought that energy-saving, economical and environment-friendly solutions will be obtained due to using less portland cement in cement production. But, it should not be forgotten that, this result may become more certainty after tests for strength and durability on analcimes which will be obtained from different regions.

Acknowledgements

This study was funded by the Scientific Research Project Unit of Ordu University under Project No: TF-1521. Also, we would like to thanks to General Directorate Of Mineral Research And Explorations, Votorantim Cimentos, Mineralogy Laboratory of Blacksea Technical University, Gördes Zeolite Company for their support and assistance.

References

[1]Erdoğan, T. Y., Beton, METU Press, Ankara, 757s., 2013.

[2]Massazza F., "Pozzolanic Cement", Cement and Concrete Composites, v:15, pp: 185-214, 1993.

[3]ASTM C 311, Standard test methods for sampling and testing fly ash or natural pozzolans for use a mineral admixture in portland-cement concrete, Annual book of ASTM standards, 1994.

[4]TS EN 450, Fly ash for concrete-Part 1: Definition, specifications and conformity criteria, Turkish Standarts Institute, Ankara, 2013.

[5]TS 25, Natural pozzolan (trass) for use in cement and concrete-Definitions, requirements and conformity criteria, Turkish Standarts Institute, Ankara, 2008.

[6]Kılınçkale F.M., "Çeşitli puzolanların puzolanik aktivitesi ve bu puzolanlarla üretilen harçların dayanımı", Chamber of Civil Engineers, Journal of Technical, pp: 1217-1229, 1996.

[7]Chan SYN, Ji X. Comparative study of the initial surface absorption and chloride diffusion of high performance zeolite, silica fume and PFA concretes. Cem Concr Compos. 1999; 21:293–300.

[8]Trnı´k, A., Scheinherrova´, L., Medved, I., Cerny, R., "Simultaneous DSC and TG analysis of high-performance concrete containing natural zeolite as a supplementary cementitious material", J Therm. Anal. Calorim., 121:67–73, 2015.

[9]Kumbasar, I., Silika mineralleri, Press of Istanbul Technical University, Istanbul, 1977.

[10]Yazıcıoğlu, Ö.F., "Investigation of usability as pozzolanic additive material of natural zeolite (analcime) in sustainable productions of cement and Concrete industry", MSc. Thesis, University of Ordu, Institute for Graduate Studies in Science and Technology, Department of Renewable Energy, 85p, 2016.

[11]Akgün, Y., Yazıcıoğlu, Ö.F.," The effect of two different natural zeolite additions on the abrasion resistance of cement mortar", Ordu University, Journal of Science and Technology, Vol:6, No: 1, 94-104, 2016.

[12]ASTM C 430, Test method for fineness of hydraulic cement by the 45-μm (No. 325) sieve, American Society for Testing and Materials, United States of America, 2005.

[13]TS EN 196-1, Methods of testing cement - Part 1: Determination of strength, Turkish Standarts Institute, Ankara, 2016.

[14]TS EN 197-1, Cement – Part 1: Composition, specification and conformity criteria for common cements, Turkish Standarts Institute, Ankara, 2012.

[15]TS 196-6, Methods of testing cement - Part 6: Determination of fineness, Turkish Standarts Institute, Ankara, 2010.

[16]Yamamoto, S., Sugiyama, S. , Matsuoka, O., Kohmura, K., Honda, T., Banno, Y., Nozoye, H., Dissolution of Zeolite in Acidic and Alkaline Aqueous Solutions As Revealed by AFM Imaging, Journal of Physical Chemistry 100, pp:18474-18472, 1996.

[17]Cizmek, A., Subotic, B., Smit, I., Tonejc, A., Aiello, R., Crea, F., Nastro, A., Dissolution of high-silica zeolites in alkaline solutions II. Dissolution of ‘activated’ silicate-1 and ZSM-5 with different aluminum content, Microporous Materials 8, pp:159-169, 1997.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June2017, pp. 194~201
Available online at:http://pen.ius.edu.ba

Ceramic Wastes Usage as Alternative Aggregate in Mortar and Concrete

Gulden Cagın Ulubeyli[1], Turhan Bilir[1], Recep Artir[2]
[1]Department of Civil Engineering, Bulent Ecevit University
[2]Department of Metallurgical and Materials Engineering, Marmara University

Article Info

Article history:

Received May29th, 2017
Revised June15th, 2017
Accepted June 17th, 2017

Keyword:

Aggregate
Ceramic Waste
Concrete
Durability Properties
Mechanical Properties

ABSTRACT

In the ceramic industry, huge amounts of wastes are generated during manufacturing and transportation processes. In order to decrease the need for landfill areas and increase environmentally harmful effects of such wastes, this industry is under pressure to finding effective ways for recycling its wastes and by-products. In addition, the construction industry requires new sources of aggregates due to running out of conventional virgin aggregates, saving energy, and protecting the environment. Therefore, recently, ceramic wastes are often used as coarse and/or fine aggregate both in mortar and concrete. In the present study, effects of using ceramic wastes as coarse and/or fine aggregate on the engineering properties of mortar and concrete are evaluated. These engineering properties are listed and compared according to their mechanical and durability properties. Reviewing of previous studies related with this subject in literature and discussion all results of the studies are conducted as the methodology of this study. Consequently, it was found out that the use of waste ceramic in the conventional concrete or mortar mix as fine/coarse aggregate is suitable as it can improve mechanical and durability properties of the concrete/mortar.

Corresponding Author:

Gulden Cagın Ulubeyli,
Department of Civil Engineering,
Bulent Ecevit University,
Farabi Campus, İncivez 67100, Zonguldak, Turkey.
Email: caginulubeyli@beun.edu.tr

1. Introduction

Recycling and reutilization of industrial waste and byproducts is a subject of great importance today in cement and concrete technology [1]. Especially ceramic wastes, which are durable, hard and highly resistant to biological, chemical and physical degradation forces, cannot be recycled by any existing process. The use of inorganic industrial residual products in the production of concrete will lead to sustainable ceramic industry ranges from 3% to 7% of daily production [2]. Therefore, construction industry can be the end user of all ceramic wastes and in this way can contribute to solve this environmental problem. The nature of construction industry, especially the concrete industry, is such that ceramic wastes can be used safely with no need for dramatic change in production and application process. On the other hand, the cost of deposition of ceramic waste in landfill will be saved and, on the other, raw materials and natural resources will be replaced, thus saving energy and protecting the environment [3].
In the present study, the effects of ceramic wastes used as fine/coarse aggregates on the properties of concrete were investigated by an in-depth literature review. Thus, the effect of these ceramic wastes on the durability and mechanical properties of concrete and mortar were presented in a detailed manner. Consequently, the use

of ceramic wastes and their effects as fine/coarse aggregates in a sustainable concrete and mortar were examined.

2. Methodology

In this study, considering the previous studies, mechanical and durability properties of concrete produced by waste ceramic addition into mortar and concrete investigated in detailed manner. Throughout the literature review, it was observed that ceramic waste was used as fine/coarse aggregate in sand/gravel in producing mortar/concrete mix. In these studies, effects of waste ceramic on the some mechanical and durability properties of concrete were investigated. In this study, mechanical properties grouped into compressive, flexural and tensile strength, elastic modulus and finally shrinkage of concrete. In addition to, durability properties grouped into water absorbtion, ultrasonic pulse velocity, chloride penetration, abrasion resistance and finally freeze-thaw resistance. Consequently, effects of waste ceramic on these properties of concrete were evaluated in a detailed manner and reasons of results were established.

3. Results and Discussion

3.1. Mechanical Properties

Mechanical properties of results were summarized in Table 1. Considering the results, waste ceramic was used as fine or/and coarse aggregate in concrete/mortar mixing. When ceramic waste was used as fine or/and coarse aggregate in concrete or mortar mixing, strength properties of concrete were increased compared with control concrete/mortar in generally. This improved incorporation of waste ceramic aggregate in the paste can be due to the more irregular shape it presents, resulting in a superior specific surface area than natural aggregate (gravel), which is rounded and thus lacks edges. Moreover, this irregular shape provides the higher bond between recycled ceramic aggregate and the paste. Furthermore, the ceramic aggregate could presented little puzzolanic activity in the surface part due to its chemical composition and grain size, this was nevertheless sufficient to react with the porltandite present in the periphery of the aggregate, giving rise to hydrated products such as calcium silicate hydrates (CSH) and calcium aluminate hydrates which present a less porous, more compact structure, forming a more stable aggregate/paste transition zone [4]. In contrast to all these studies, a few studies consisted of low strength properties compared to conventional concrete/mortar detected [5]-[6]. In these studies, the reason of strength loss was explained as ceramic aggregate having lower density and strength compared to conventional aggregate [6].

3.2. Durability Properties

Durability properties of results were summarized in Table 2. According to results of studies, chloride penetration, capillarity water absorbtion, abrasion resistance, freeze-thaw resistance, high temperature resistance, gas permeability and finally, ultrasonic pulse velocity properties were investigated in previous studies. Especially, capillary water absorbtion, oxygen and gas permeability of concrete produced waste ceramic as fine/coarse aggregate were improved or similar compared to conventional concrete. But, these properties were determined as worse compared to control specimen [7]-[8]. This decrease can be due to both the higher water absorption coefficient in waste ceramic aggregate and the effect of this waste ceramic aggregate on the pore system [9]. In generally, freeze-thaw durability and high temperature resistance, chloride penetration and abrasion resistance performance of concrete produced by waste ceramic were better than conventional concrete due to the high mechanical and the puzolonic properties of the ceramic aggregate [4].

Table 1. Comparison of some results for mechanical properties.

		Mixing Ratio of Concrete						
Type of Product	**Using of Waste Ceramic In The Concrete**	**Waste Ceramic Type**	**Waste Ceramic Ratio**	**Comparison Criteria**	**Experiments**	**Curing Day**	**Mechanical Property Findings**	**Ref.**
Normal Mortar Mixing	As Fine Aggregate in Sand	Earthenware ceramic waste (CWA)	(10-20-30-40-50-100)%	Mortar mix produced by %100 natural sand	-Compressive Strength	7, 14 and 28	All mortar mixes containing CWA gave higher compressive strength than that of the control mortar (42.2 MPa at 28 days), and that the compressive strength increased with increasing use of CWA up to 50% by weight (50.2 MPa at 28 days).	[10]
Normal Mortar Mixing	As Fine Aggregate in Sand	Porcelain insulator waste (CWA)	100%	Mortar mix produced by %100 typical river sand (RS)	-Compressive Strength	7, 28, 91	The compressive strength of the CWA mortars in which the CWA was used as received from the recycle plant was relatively similar to that of the corresponding RS mortars.	[11]
Conventional Concrete	As Fine Aggregate in Sand	Earthenware ceramic waste (CWA)	(50-100)%	Concrete mix produced by %100 natural sand	-Compressive Strength	7 and 28	The compressive strength at 28 days of (CWA) concrete increased with the use of CWA at 50% by weight, where it reached optimum strength (40 MPa). This was an increase of 7.5% compared to the control concrete. Thereafter a decline in compressive strength was observed, with a slightly lower value (38.5 MPa) at 100% CWA.	[10]
Conventional Concrete	As Fine Aggregate in Sand	White ceramic powder	(10-20-30-40-50)%	Concrete mix produced by %100 natural sand	-Compressive Strength -Tensile (Brazilian) Test -Flexi-traction Test	7, 14, 28	The use of white ceramic powder to substitute part of the sand does not reduce compressive strength but rather gives an appreciable increase in strength. Regarding traction resistance, the introduction of white ceramic powder does not give any appreciable difference compared with the control concrete.	[12]
Conventional Concrete	As Fine Aggregate in Sand	Crushed ceramic waste (CC)	(40- 50-60)%	Concrete mix produced by %100 conventional crushed fine aggregates	-Compressive Strength	7, 28, 90, 365	It can be seen that the compressive strength of CC concrete mixes with 40%, 50% and 60% fine aggregate replacement with CC were higher than the control specimen at all ages .However, the rate of increase of strength decreases with the increase in CC content.	[13]
Conventional Concrete	As Fine Aggregate in CEN Reference Sand	Sanitary ceramic waste	(10, 15 and 20)%	Concrete mix produced by %100 natural sand	-Compressive Strength -Flexural Strength	2, 7, 14, 28 and 56	Incorporation of ceramic waste aggregates led to a systematic improvement of the mechanical properties, the benefits increasing with the addition rate.	[14]
Conventional Concrete	As Fine and coarse aggregate in sand and gravel	Brick, blocks and roof tiles - wall, floor tiles and sanitary ware	100% (for both fine and coarse)	Concrete mix produced by %100 natural fine and coarse aggregate	-Compressive Strength	7, 14, 28, 56 and 90	The results obtained indicate that the strength is higher for concrete with both replacements coarse ceramic aggregate and ceramic sand than control concrete with traditional aggregates.	[15]
Conventional Concrete	As Fine and coarse aggregate in sand and gravel	Sanitary ceramic ware waste	100% (for both fine and coarse)	Concrete mix produced by %100 natural fine and coarse aggregate	-Compressive Strength -Tensile Strength	28	Compressive strength of such concrete was higher of 12% and tensile strength of 30% in comparison to concrete with sand and gravel aggregate.	[16]

Table 1. Comparison of some results for mechanical properties (cont.).

		Mixing Ratio of Concrete						
Type of Product	**Using of Waste Ceramic In The Concrete**	**Waste Ceramic Type**	**Waste Ceramic Ratio**	**Comparison Criteria**	**Experiments**	**Curing Day**	**Mechanical Property Findings**	**Ref.**
High-Performance Concrete	As Fine and coarse aggregate in sand and gravel	Earthenware ceramic waste	15-30% of natural sand and 20-50-100% of coarse mixed aggregates.	Concrete mix produced by %100 natural river sand mixes and dolomitic gravel	-Compressive Strength -Flexural Strength -Split Tensile Strength -Elastic Modulus	1, 7, 28 and 180	Concrete made with fine ceramic aggregate achieved a higher compressive, flexural, splitting tensile strength and elastic modulus strength in comparison to that of control concrete. But, the concrete made with more than 20% of coarse ceramic aggregates achieved a lower compressive, flexural, splitting tensile strength and elastic modulus to that of control concrete.	[8]
Conventional Concrete	As Coarse Aggregate	Sanitary ceramic waste	(15, 20 and 25)%	Concrete mix produced by %100 natural coarse aggregate.	-Compressive Strength -Split Tensile Strength	7, 28 and 90	The mechanical behavior, both in terms of compression and splitting tensile strength, was better for the recycled concretes than for the reference concrete.	[4]
Conventional Concrete	As Coarse Aggregate	Ceramic Waste	100%	Concrete mix produced by %100 conventional coarse aggregate	-Compressive Strength	28	The concrete mixes containing recycled ceramic waste aggregates achieve strength levels between 80 to 95% compared to the conventional concrete.	[17]
Conventional Concrete	As Coarse Aggregate	Ceramic electrical insulator wastes	100%	Concrete mix produced by %100 conventional crushed stone coarse aggregate	-Compressive Strength -Flexural Strength -Split Tensile Strength -Elastic Modulus	28	The compressive, splitting tensile and flexural strengths of ceramic waste coarse aggregate concrete are lower by 3.8, 18.2 and 6% respectively when compared to conventional concrete, but ceramic waste coarse aggregate concrete possesses lower tensile to compressive strength ratio.	[18]
Conventional Concrete	As Coarse Aggregate	Crushed tiles	(50-100)%	Concrete mix produced by %100 conventional crushed stone coarse aggregate	-Compressive Strength -Flexural Strength -Split Tensile Strength	7, 28	In general, concretes made with crushed tile as coarse aggregate showed higher compressive, tensile, and flexural strengths than control concrete.	[19]
Non-Structural Concrete	As Coarse Aggregate	Ceramic hollow bricks	(33, 66 and 100)%	Concrete mix produced by %100 coarse limestone aggregate	-Compressive Strength -Flexural Strength	28	The compressive and flexural strength, decreased with the percentage of replacement of limestone aggregates with ceramic aggregates increase. The decrease in compressive strength is higher than that in the flexural strength.	[6]
Portland Blast Furnace Cement Type B Concretes	As Coarse Aggregate	Porous ceramic waste aggregate (PCA)	(10 and 20)%	Concrete mix produced by %100 crushed gravel aggregate	-Compressive Strength -Shrinkage	3, 7 and 28 (internal curing)	A 10% replacement of coarse aggregate by PCA was more effective in improving compressive strength than a 20% replacement by PCA at the early ages of 3 and 7 days, independent of exposure conditions. Internal curing using PCA to replace part of the coarse aggregate was not effective in reducing autogenous shrinkage.	[20]

Table 2. Comparison of some results for durability properties.

		Mixing Ratio of Concrete					
Type of Product	**Using of Waste Ceramic In The Concrete**	**Waste Ceramic Type**	**Waste Ceramic Ratio**	**Comparison Criteria**	**Experiments**	**Durability Results**	**Ref.**
Normal Mortar Mixing	As Fine Aggregate in Sand	Porcelain insulator waste (CWA)	100%	Mortar mix produced by %100 typical river sand (RS)	-Chloride Penetration	It quantitatively indicated that the CWA mortars had lower apparent chloride diffusion coefficient than the RS mortars	[11]
Conventional Concrete	As Fine Aggregate in Sand	Crushed ceramic waste (CC)	(40- 50-60)%	Concrete mix produced by %100 conventional crushed fine aggregates	-Abrasion Resistance -Chloride Penetration	Abrasion resistance of concrete was strongly influenced by its compressive strength and crushed ceramic. Measurement of chloride penetration depths correlated well with the differences between additive type and replacement percentage of the mixtures. Crushed ceramic 60% specimens were considerably more resistant to chloride ingress than those of other specimens.	[13]
Conventional Concrete	As Fine Aggregate in CEN Reference Sand	Sanitary ceramic waste	(10, 15 and 20)%	Concrete mix produced by %100 natural sand	-Freeze-Thaw Resistance	The freeze-thaw resistance results were concluding that ground ceramic waste addition did not have any influence on compressive strength up to 25 cycles, the observed behavior being similar for all tested mortars. Conversely, freeze-thaw was found to affect negatively the flexural strength of all tested mortars, the reduction increasing with the ceramic waste content.	[14]
Conventional Concrete	As Fine and coarse aggregate in sand and gravel	Sanitary ceramic ware waste	100% (for both fine and coarse)	Concrete mix produced by %100 natural fine and coarse aggregate	-High Temp. Resist. -Abrasion Resistance	Abrasion resistance of concrete with ceramic sanitary ware aggregate is higher by about 20% than abrasion resistance of gravel concrete. Compressive strength of concrete with ceramic aggregate decreased immediately after heating by 46%, in comparison to strength of unheated concrete, whereas tensile strength decreased by 54%; strength loss was similar to other types of concrete, however high initial strength made the strength of this concrete still high after heating.	[16]
Conventional Concrete	As Fine and coarse aggregate in sand and gravel	Brick, blocks and roof tiles - wall, floor tiles and sanitary ware	100% (for both fine and coarse)	Concrete mix produced by %100 natural fine and coarse aggregate	-Capillary Water Absorb. -Oxygen Permeability -Chloride Penetration	As for capillarity water absorption coefficients the differences are rather important since capillary water absorption for control concrete (with traditional aggregates) almost doubles the capillarity water absorption coefficient of ceramic aggregates based concrete. The oxygen permeability results confirm the good performance of the concrete mixtures with ceramic aggregates. As for the chloride diffusion it once more confirms the good performance of ceramic sand and coarse ceramic aggregate based concrete.	[15]
High-Performance Concrete	As Fine and coarse aggregate in sand and gravel	Earthenware ceramic waste	15-30% of natural sand and 20-50-100% of coarse mixed aggregates.	Concrete mix produced by %100 natural river sand mixes and dolomitic gravel	-Ultrasonic Pulse Veloc. -Capillary Water Absorb. -Chloride Penetration	Although the capillary absorption coefficient and ultrasonic pulse velocity values were worse than those of conventional concrete, the chloride ion penetration, after 180 days, was lower in concretes made with ceramic fine aggregates.	[8]

Table 2. Comparison of some results for durability properties (cont.).

		Mixing Ratio of Concrete					
Type of Product	**Using of Waste Ceramic In The Concrete**	**Waste Ceramic Type**	**Waste Ceramic Ratio**	**Comparison Criteria**	**Experiments**	**Durability Results**	**Ref.**
Non-Structural Concrete	As Coarse Aggregate	Ceramic hollow bricks	(33, 66 and 100)%	Concrete mix produced by %100 coarse limestone aggregate	-Capillary Water Absorb. -Immersion Water Absorb -Abrasion Resistance	The durability of this type of concrete may turn out to be its major insufficiency, since water absorption either by immersion or capillarity increases very regularly and significantly with the proportion of ceramic aggregates on the concrete mix. Abrasion resistance is precisely the one in which the concrete produced with recycled ceramic aggregates shows an excellent performance, even better than the reference concrete.	[21]
Conventional Concrete	As Coarse Aggregate	Sanitary ceramic waste	(20 and 25)%	Concrete mix produced by %100 natural coarse aggregate.	-Gas Permeability	According to test results, micro-porosity and gas permeability, O_2 and CO_2 permeability were similar in the reference concrete and the concretes containing recycled sanitary ware as a partial replacement for conventional aggregate.	[7]
Conventional Concrete	As Coarse Aggregate	Sanitary ceramic waste	(20 and 25)%	Concrete mix produced by %100 natural coarse aggregate.	-Freeze-Thaw Resistance	Sanitary ware industry aggregate is more resistant to temperature change than natural coarse aggregate. The new concrete is more freeze-thaw resistant than conventional concrete. The scaling rate is lower and the cracks are narrower in recycled concrete. Both effects are accentuated with rising replacement ratios.	[9]
Conventional Concrete	As Coarse Aggregate	Sanitary ceramic waste	(20 and 25)%	Concrete mix produced by %100 natural coarse aggregate.	-Water Resistance -Porosity -Sorptivity	The maximum depth of water penetration is no greater in recycled aggregate than natural aggregate concretes, and although the average value is somewhat higher in the former, it never exceeds 30 mm. The inclusion of ceramic sanitary ware aggregate raises total porosity slightly and modifies pore size distribution, with an increase in the volume of capillary pores at the expense of macro pores. The concretes with recycled ceramic aggregate have greater sorptivity than conventional concretes, since the values are consistently under 3 $mm/h^{0.5}$, these may consequently be regarded as durable materials.	[4]
Conventional Concrete	As Coarse Aggregate	Ceramic electrical insulator wastes	100%	Concrete mix produced by %100 conventional crushed stone coarse aggregate	-Capillary Water Absorb. -Sorptivity -Chloride Penetration	The basic trend of permeation characteristics of the ceramic electrical insulator waste coarse aggregate concrete is similar to those of the conventional concrete. The permeation characteristic values increase with increase in water–cement ratio for both the ceramic electrical insulator waste coarse aggregate concrete and the conventional concrete.	[18]

4. Conclusions

In this study, effects of waste ceramic on some mechanical and durability properties of conventional concrete were investigated. Considering all of the results and the findings in the literature, it was found that, using of waste ceramic in the conventional concrete as fine/coarse aggregate was positively affected on these mechanical and durability properties of concrete. Consequently, the green and sustainable concretes would be obtained by partial substitution of waste ceramic aggregates from different ceramics industry can be used for structural purposes.

References

[1] F. Puertas, M. T. Blanco-Varela, and T. Vazquez, "Behavior of cement mortars containing an industrial waste from aluminum refining Stability in $Ca(OH)_2$ solutions," Cement and Concrete Research, vol. 29, pp. 1673-1680, 1999.

[2] M. Fernandes, A. Sousa, and A. Dias, "Environmental impact and emissions trade ceramic industry- A case study," Portuguese Association of Ceramic Industry APICER, Portuguese, 2004.

[3] F. Pacheco-Torgal, and S. Jalali, "Compressive strength and durability properties of ceramic wastes based concrete," Materials and Structures, vol. 44, pp. 155-167, 2011.

[4] C. Medina, M. I. Sanchez de Rojas, and M. Frias, "Reuse of sanitary ceramic wastes as coarse aggregate in eco-efficient concretes," Cement & Concrete Composites, vol. 34, pp. 48-54, 2012.

[5] R. M. Senthamarai, and P.D. Manoharan, "Concrete with ceramic waste aggregate," Cement & Concrete Composites, vol. 27, pp. 910-913, 2005.

[6] J. Brito, A.S. Pereira, and J.R. Correia, "Mechanical behaviour of non-structural concrete made with recycled ceramic aggregates", Cement & Concrete Composites, vol. 27, pp. 429-433, 2004.

[7] C. Medina, M. Frias, M. I. Sanchez de Rojas, C. Thomas, and J.A. Polanco, "Gas permeability in concrete containing recycled ceramic sanitary ware aggregate," Construction and Building Materials, vol. 37, pp. 597-605, 2012.

[8] A. Gonzalez-Corominas, and M. Etxeberria, "Properties of high performance concrete made with recycled fine ceramic and coarse mixed aggregates," Construction and Building Materials, vol. 68, pp. 618-626, 2014.

[9] C. Medina, M. I. Sanchez de Rojas, and M. Frias, M, "Freeze-thaw durability of recycled concrete containing ceramic aggregate," Journal of Cleaner Production, vol. 40, pp. 151-160, 2013.

[10] P. Torkittikul, and A. Chaipanich, "Utilization of ceramic waste as fine aggregate within Portland cement and fly ash concretes," Cement & Concrete Composites, vol. 32, pp. 440-449, 2010.

[11] H. Higashiyama, K. Yamauchi, M. Sappakittipakorn, M. Sano, and O. Takahashi, "A visual investigation on chloride ingress into ceramic waste aggregate mortars having different water to cement ratios," Construction and Building Materials, vol. 40, pp. 1021-1028, 2013.

[12] V. Lopez, B. Llamas, A. Juan, C.M. Moran, and I. Guerra, "Eco-efficient concretes: impact of the use of white ceramic powder on the mechanical properties of concrete," Biosystems engineering, Vol. 96, pp. 559-564, 2007.

[13] H. Binici, "Effect of crushed ceramic and basaltic pumice as fine aggregates on concrete mortars properties," Construction and Building Materials, vol. 21 pp. 1191-1197, 2007.

[14] W. Jackiewicz-Rek, K. Załęgowski, A. Garbacz, and B. Bissonnette, "Properties of cement mortars modified with ceramic waste fillers," Procedia Engineering, vol. 108, pp. 681-687, 2015.

[15] F. Pacheco-Torgal, and S. Jalali, "Reusing ceramic wastes in concrete," Construction and Building Materials, vol. 24, pp. 832-838, 2010.

[16] A. Halicka, P. Ogrodnik, and B. Zegardlo, "Using ceramic sanitary ware waste as concrete aggregate," Construction and Building Materials, vol. 48, pp. 295-305, 2013.

[17] A.M.M. Al Bakri, M. N. Norazian, H. Kamarudin, M.A.A. Mohd Salleh, and A. Alida, "Strength of concrete based cement using recycle ceramic waste as aggregate," Advanced Materials Research, vol. 740, pp. 734-738, 2013.

[18] R.M. Senthamarai, P.D. Manoharan, and D. Gobinath, "Concrete made from ceramic industry waste: Durability properties," Construction and Building Materials, vol. 25, pp. 2413-2419, 2011.

[19] A.R. Khaloo, "Crushed Tile Coarse Aggregate Concrete," Cement, Concrete, and Aggregates, vol. 17, pp. 119-125, 1995.

[20] R. Sato, A. Shigematsu, T. Nukushina, and M. Kimura, "Improvement of properties of portland blast furnace cement type b concrete by internal curing using ceramic roof material waste," Journal of Materials in Civil Engineering, vol. 23, PP. 777-782, 2011.

[21] J.R. Correia, J. Brito, A.S. Pereira, "Effects on concrete durability of using recycled ceramic aggregates," Materials and Structures, vol. 39, pp. 169-177,2006.

BIBLIOGRAPHY OF AUTHORS

Gülden Çağın Ulubeyli was born on November 3rd of 1982 in Bursa, Turkey. She completed her primary and middle school educations in Erzurum. Following her high school education in Erzurum High School in 2000, she was graduated from Civil Engineering Department of Atatürk University in 2006 and Chemical Engineering Department in 2007. She graduated her M.Sc. education at Marmara University, Institute for Graduate Studies in Pure and Applied Sciences, Metallurgy and Materials Engineering Program in 2011. She is currently studying her PhD. education at Marmara University, Institute for Graduate Studies in Pure and Applied Sciences, Metallurgical and Materials Engineering Program since 2011. Also, she has been working as a Research Assistant in Civil Engineering Department of Bulent Ecevit University since 2009.

Turhan Bilir is an Associate Professor and the Head of the Department of Civil Engineering Bülent Ecevit University, Zonguldak, Turkey. He worked for Department of Civil Engineering Bülent Ecevit University as an Assistant Professor between 2011 and 2014. He received his BSc degree from Eskisehir Osmangazi University at 2001, his MSc degree from Zonguldak Karaelmas University at 2005 and his PhD. degree from Eskisehir Osmangazi University at 2010. His research interests include durability of cement and concrete, the use of wastes and by-products in the cement and concrete industry, composite materials and models, lightweight aggregates and concrete, sustainable development in cement and concrete industry, and restraint drying shrinkage of concrete.

Recep Artır is a lecturer and Professor of Metallurgical and Materials Engineering. He received his BSc degree in Metallurgical Engineering from İstanbul Technical University, Turkey in 1985. He received his MSc degree in Metallurgical Engineering from Yıldız University, İstanbul, Turkey in 1988 and his PhD. degree from Sheffield University in 1994 in the UK. Currently, he carries out his teaching and research activities in Metallurgical and Materials Engineering department at Marmara University. His research interests include iron and steel production, recycling of industrial wastes, ceramic and refractory materials, biomaterials and surface modification of materials.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June2017, pp. 202~209
Available online at:http://pen.ius.edu.ba

The Finite Element Analysis and Geometry Improvements of Some Structural Parts of a Diesel Forklift Truck

Ömer Yavuz Bozkurt[1], İhsan Cihan Dai[2], Özkan Özbek[1]
[1]Mechanical Engineering Department, Gaziantep University, Gaziantep, Turkey
[2]Sanko Machine, ARGE Department, Gaziantep, Turkey

Article Info

Article history:

Received May 30th, 2017
Revised June 15th, 2017
Accepted June17th, 2017

Keyword:

Finite element analysis
Forklift
Msc SimXpert Nastran

ABSTRACT

In this work, static analyses of structural parts of a diesel forklift were performed using Finite Element Method and possible modifications based on the original geometry of parts were utilized with respect to stress distributions at critical region to improve reliability of the forklift design. The analyses were carried out according to standard regulations related with the examined parts. The structural parts of forklift such as chassis and head guard were analysed under compulsion loading conditions. The improvements in relevant parts were demonstrated by the comparison of stress values of original and modified geometries. The finite element analyses were carried out using MSC SimXpert Nastran Finite Element software package.

Corresponding Author:

Özkan Özbek,
Mechanical Engineerin Department,
Gaziantep University,
27310, Gaziantep, Turkey.
Email: ozkanozbek@gantep.edu.tr

1. Introduction

Forklift is a relatively small industrial vehicle used to carry industrial goods in a short distances by two power-operated forks at the front. It is also called as a lift truck, a fork truck, or a forklift truck. A forklift can be used in numerous places such as; warehouses, factories, farms, shipping yards, construction sites, supermarkets, and much more. Several different forklift models are found in literature. They can be categorized based on their design, i.e. capabilities, size and methods of operation.
The tests or testing steps are one of the most important and necessary part of a design procedure. Several tests must be performed to develop a new product. Due to requirement of long time durations and production of a prototype, destructive and non-destructive physical tests are generally expensive and adversely affect the product's time to enter the market. In today's world, computer simulations are carried out to improve the efficiency of design procedures in terms of cost and time by reducing or eliminating the need of physical tests. Finite element method (FEM) is the most widely used numerical analysis method in the computer simulations. The FEM does not require a physical prototype production and it can be used to analyse any parts/components of the whole system under certain operating conditions. Also, it permits improvements in the reliability of product by changing the design according to the results of analysis.
In the literature, there are several articles on the open literature associated with the finite element analysis of forklifts. Bhagat et al. [1] developed the CAD model of a translation carriage for reach truck and performed the static analyse of it under various loading and boundary conditions using finite element analysis in ANSYS environment. Doçi et al. [2] examined the structural behaviours of forklift under dynamic loadings and specified the parameters that affect the dynamic behaviours of forklift. Meshram [3] developed 3D models for the forklift mast with a change in geometry to perform of structural analysis using finite element method.

Also, in terms of stress distribution, the performance of structural steel and gray cast iron were compared using the same boundary conditions. Rane et al. [4] carried out topology optimization technique for the design of forklift chassis to reduce the weight without changing the working conditions of forklift. Cline [5] conducted fatigue analysis of forklift forks applying loads at two different positions; centred and offset. Miralbes et al. [6] designed the crane gibs and pallet box lock for a forklift truck using finite element analysis. The boundary conditions were provided according to the forklift truck regulations. Stoychev and Chankov [7] proposed a dynamic model to investigate the stresses for the lifting installation of a forklift truck. Todorov et al. [8] constructed a virtual design of a forklift transmission module and improved it by executing thermal and structural analysis with finite element method.
In this paper, some of the mechanical construction parts of a diesel forklift with three ton capacity is analysed using finite element method and geometry changes on 3D solid model of these forklift construction parts are applied to improve the reliability of design by reducing stress values at critical sections.

2. Geometrical Vıew and Technical Parameters

General view of the diesel forklift marked with major parts is shown in Fig. 1 and some of its technical parameters such as carrying capacity, dimensions, engine power and driving speed are presented in Table 1.

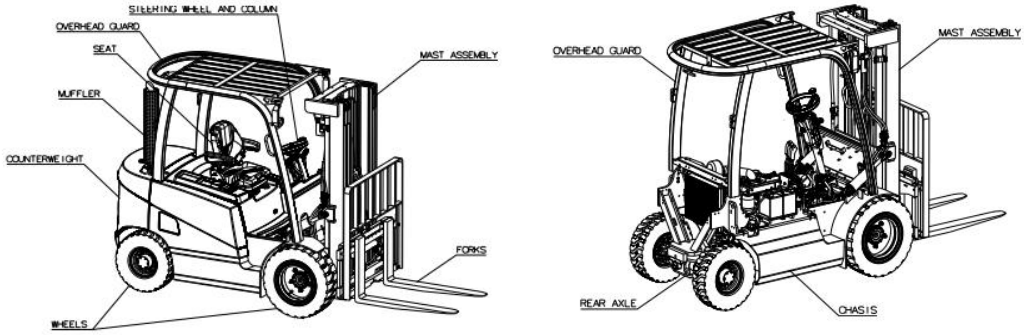


Figure 1. General view of a diesel forklift.

Table 1. Diesel forklift technical parameters

Power unit	Diesel
Carrying capacity/load	3000 kg
Load centre	500 mm
Wheel base	1720 mm
Weight	4500 kg
Tilt angle, mast/fork carriage forwards	6°
Tilt angle, mast/fork carriage backwards	10°
Lift height	3230 mm
Overall length	3757 mm
Fork thickness	45 mm
Fork width	100 mm
Fork length	1000 mm
Fork carriage DIN 15173	2A
Turning radius	2400 mm
Driving speed with load	18.2 km/h
Driving speed without load	19.5 km/h
Engine Power	35,5 kW @ 2400 rpm

3. Analysis of Chassis

The chassis is the main supporting structure of the forklift truck which all other components are attached. The 3D solid model for the chassis of forklift truck is shown in Fig. 2. The calculations of external loads are carried out using static loading, rigid connection member and linear-elastic material behaviour assumptions.

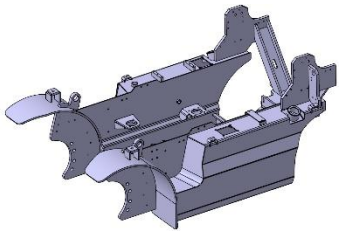


Figure 2. The 3D solid model of forklift chassis.

The maximum lifting capacity of forklift truck were analysed as 3000 kg. According to the ISO 3691-1:2011 standard, the structural components of the truck and its attachments shall carry the static load of 1.33×3000 kg. It is the rated capacity at standard lift height and standard load centre distance with respect to the information on the capacity plate.

The various loads acting on the chassis are shown in Fig. 3. The forces of tilt cylinders (F_1), total weight of cabin with seat, bonnet and operator (F_2), total weight of counterweight and muffler (F_3), weight of radiator (F_4), total weight of rear axle with wheels (F_5), and total weight of engine with transmission (F_6) are calculated as 93.227 kN, 2.943 kN, 17.462 kN, 0.294 kN, 1.589 kN and 7.700 kN, respectively.

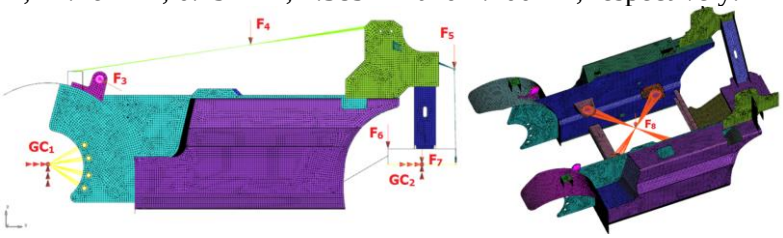


Figure 3. Loads acting on chassis.

The forces of tilt cylinders were examined using loading process of mast assembly at standard lift height under overload condition. The free body diagram of mast assembly is shown in Fig. 4. The mass of mast assembly is 1000 kg. The W_1 and W_2 are the weights of pay load and mast assembly, respectively, and are calculated as W_1=39.142 kN, W_2=9.81 kN.

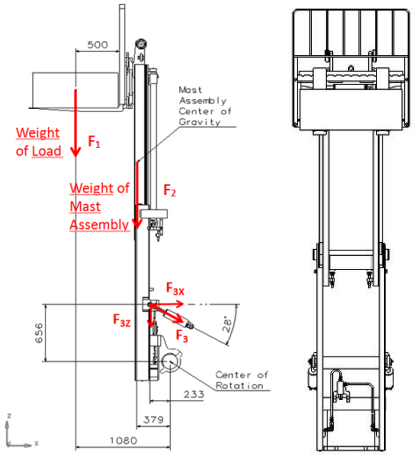


Figure 4. Free body diagram of mast assembly at standard lift height under overload condition.

The solid model, shown in Fig. 2, is meshed with 57289 elements in SimXpert Structure Analysis program. The finite element model of chassis is shown in Fig. 5. The chassis is made of St52-3 and the mechanical properties of St52-3 are given in Table 2.

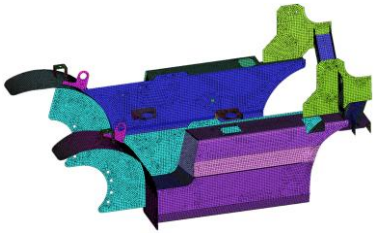


Figure 5. Finite element model of chassis.

Table 2. The mechanical properties of St52-3

Material	St52-3
Yield Stress (MPa)	355
Ultimate Stress (MPa)	530
Poisson's Ratio	0.3
Young's Modulus (GPa)	210

The analysis of chassis is carried out in case of overload and standard lifting height, and the results are shown in Fig. 6. It is shown that the maximum von Mises stress is calculated as 257 MPa at the connection bracket of tilt cylinders. The resulting stress is below the yield stress value of St52-3 material. So, there is no plastic deformation on this bracket. However, a stress concentration is shown and a design revision in geometry of bracket can be done to reduce stress values.

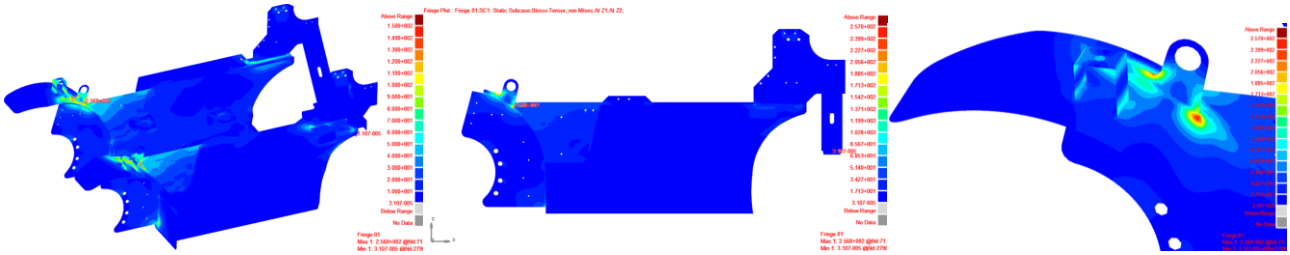


Figure 6. The FEA results of chassis. (a) Isometric view of chassis fem result; (b) Side view of chassis fem result; (c) Maximum Von Mises Stress in Tilt Cylinder Connection Bracket.

The front and rear tips of connection bracket show 232 MPa and 257 MPa for the magnitude of von Mises stress. These tip points are marked as A and B, respectively. Two new geometry is designed to improve reliability of connection bracket by reducing stress values. Finite element analysis of chassis have been performed for the new connection bracket designs and the results in terms of von Mises stress distribution are shown in Fig. 7. The first design revision in geometry made possible to reduce maximum von Mises stress to 214 MPa from 257 MPa and second one was reduced to 136 MPa. The von Mises stress comparisons of original and revised geometries of connection bracket is given in Table 3. As seen in Table 3, the factor of safety with respect to connection bracket design was increased from 1.38 to 2.08

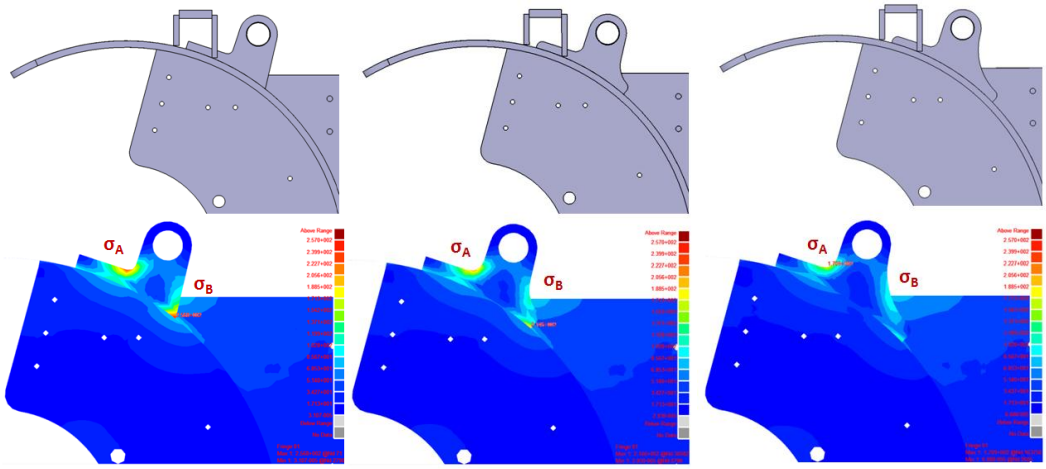


Figure 7. a) The original connection bracket, b) First revision of connection bracket, c) Second revision of connection bracket.

Table 3. Comparison of von misses stresses of tilt cylinder connection bracket

Von Mises Stress	**Original**	**Revision-1**	**Revision-2**
σ_A (MPa)	232	206	171
σ_B (MPa)	257	214	136
Factor of Safety	1.38	1.66	2.08

4. Analysis of Head Guard

The forklift trucks can be very dangerous. Serious or fatal injuries from forklift incidents, especially for roll-overs, can be happened for the forklift operators. The forklift manufacturers have formal responsibility for designing forklifts with protective structures that guard forklift operators under certain conditions. In this section, ROPS (Roll-over protective structures) test of forklift truck was simulated using finite element analysis. The simulation was carried out in accordance to EN ISO 3471 standard. Solid model of head guard and seated operator are given in Fig. 8. The model of seated operator is prepared as described in EN ISO 3411 standard and it is positioned to the sit point.

Figure 8. a) Forklift Head Guard Solid Model b) Seated Operator.

In the ROPS analysis, the material of head guard was identified as St52-3. The stress values can exceed the yield value according to ROPS analysis. Therefore, the ROPS analysis of head guard is solved as a nonlinear analysis. Stress-strain values of St52-3 material are shown in Fig. 9.
The applied load and energy of the load shall be met at least a certain level in the ROPS test. The stress values can be over the yield stress value to satisfy this requirement and due to this possibility ROPS analysis was performed as nonlinear analysis. The amount of required lateral, vertical and longitudinal loads which are formulated in relation to the weight of forklift are given in EN ISO 3471 standard. The weight of the forklift was presented in Table 1. According to EN ISO 3471 standard, forklift truck is classified in the wheeled earth-moving machine category, and the lateral load, lateral load energy, vertical load and longitudinal load are calculated as follows:

$$F_{lateral}=6\times M=6\times 4500=27 \text{ kN} \quad (1)$$

$$E_{lateral}=12500\times[(M\div 10000)]^{1.25}=12500\times[(4500\div 10000)]^{1.25}=4.607 \text{ kJ} \quad (2)$$

$$F_{vertical}=19.6\times M=19.6\times 4500=88.2 \text{ kN} \quad (3)$$

$$F_{longitudinal}=4.8\times M=4.8\times 4500=21.6 \text{ kN} \quad (4)$$

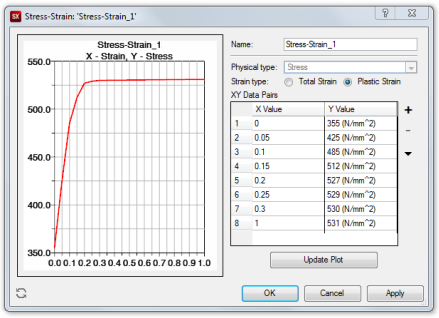


Figure 9. Stress-strain values of St 52-3 material.

The finite element model of head guard, shown in Fig. 10, has been formed from the solid model presented in Fig. 8. It has 22909 elements and in general consists of quadrilateral elements. The load distribution devices used for the load application was also modelled with solid mesh.

Figure 10. Finite Element Model of Head Guard.

The prescribed boundary conditions and applied loads on the head guard for the lateral, vertical and longitudinal loadings are shown in Fig. 11. The load distribution devices for the loading procedures are also shown in Fig. 11. The lateral force, $F_{lateral}$, vertical force, $F_{vertical}$, and longitudinal force, $F_{longitudinal}$, were calculated as 27 kN, 88.2 kN and 21.6 kN, respectively. FC_1, FC_2, FC_3, FC_4, FC_5, FC_6, FC_7, FC_8, FC_9, FC_{10}, FC_{11} and FC_{12} show that all degrees of freedom for connection parts of the head guard are restrained.

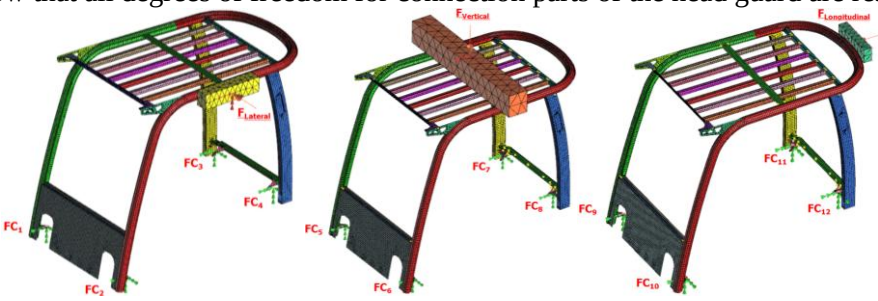


Figure 11. Loading Cases of Head Guard. (a)$F_{lateral}$ force, FC_1, FC_2, FC_3 and FC_4 Fixed Constraints; (b) $F_{vertical}$ force, FC_5, FC_6, FC_7 and FC_8 Fixed Constraints; (c) $F_{longitudinal}$ force, FC_9, FC_{10}, FC_{11} and FC_{12} Fixed Constraints.

The lateral loading procedure was carried out using the load distribution device. At the end of the lateral loading, maximum stress value was measured as 411 MPa. Maximum deformation was measured as 87 mm. During the loading, head guard didn't enter to the seated operator area, but it has a permanent deformation. FEM results of lateral loading are shown in Fig. 12 and load-displacement curve is given in Fig. 13.

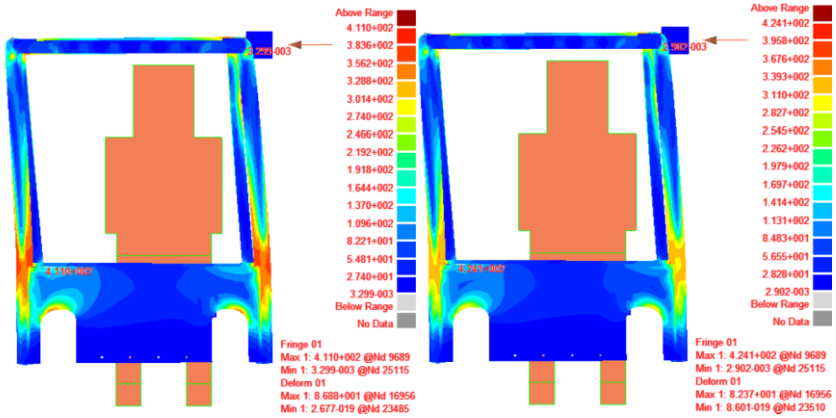


Figure 12. FEM results of Lateral Loading (a) Maximum Loading; (b) Load Removed.

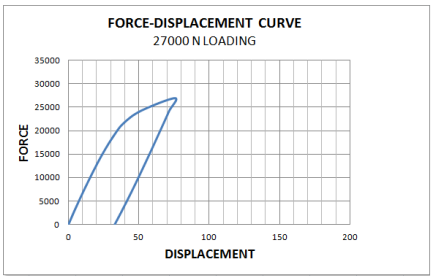


Figure 13. Force-Displacement curve under the application of 27 kN load.

During the loading period, the head guard structure was permanently deformed but not in the operator area defined according to the specified standards. With the 1373 J energy generated by applying load of 27 kN, the energy requirement of 4607 J defined in the ROPS standard was not met. For this reason, a load of 32 kN was applied by increasing the amount of load to meet the energy requirement, and the energy requirement of the ROPS standard was met by the 4758 J energy output. The maximum tensile value obtained at 32 kN loading was 481 MPa and the maximum deformation value at force application point was determined as 189.5 mm. The results of the finite element method obtained from lateral load of 32 kN are shown in Fig. 14. The load-displacement curve graph is shown in Fig. 15. During the loading period, the head guard did not enter the operator area.

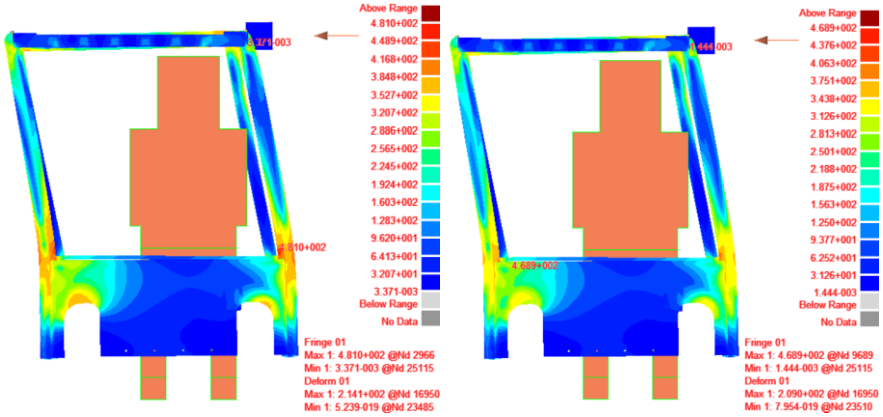


Figure 14. FEM results of Lateral Loading (a)Maximum Loading; (b) Load Removed.

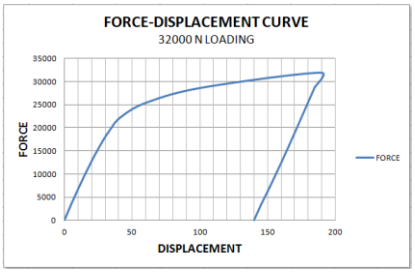


Figure 15. Force-Displacement curve under the application of 32 kN load.

Vertical loading was carried out using the long load distribution device from the cabin. At the end of the vertical loading, maximum stress value was measured as 359 MPa. Maximum deformation was measured as 7.8 mm. During the loading, head guard didn't enter to the seated operator area. Head guard has a permanent deformation, no cracks have occurred in the cabin. FEM results of vertical loading was shown in Fig. 16.

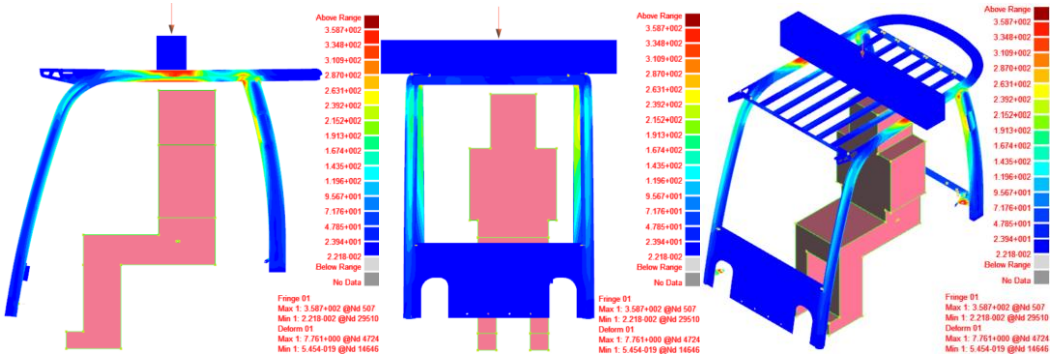


Figure 16. FEM results of Vertical Loading (a) Isometric view of fem result; (b) Front view of fem result; (c) Side view of fem result.

Longitudinal loading was carried out using the load distribution device. At the end of the longitudinal loading, maximum stress value was measured as 354 MPa. Maximum deformation was measured as 17 mm. During

the loading, head guard didn't enter to the seated operator area. Head guard has no permanent deformation, no cracks have occurred in the cabin. FEM results of longitudinal loading was shown in Fig. 17.

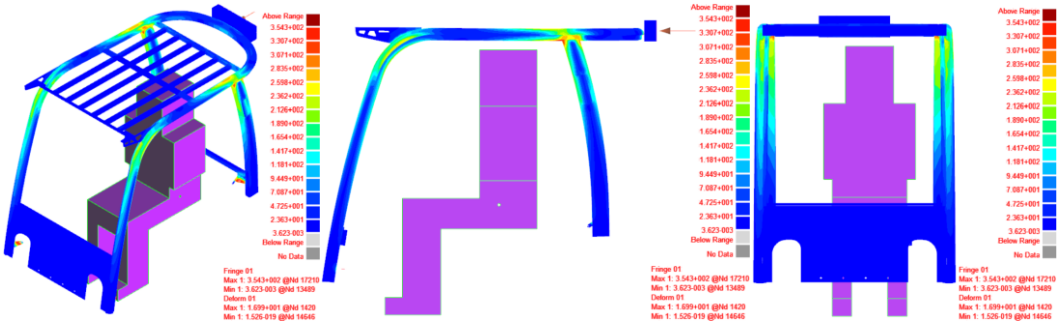


Figure 17. FEM results of Longitudinal Loading (a) Isometric view of fem result; (b) Front view of fem result; (c) Side view of fem result.

5. Conclusions

In this study, static analysis of some structural parts such as chassis, head guard of a diesel forklift truck was performed by using finite element method. Critical regions with high stress values were determined according to the analysis results and design geometries were changed to reduce stresses in there. The analysis results that belong the original models and modified models were compared. The analysis of modified models with new geometries showed that the reliability of the design was improved by lower stresses. For operator safety, the maximum stress and deformation values that can occur in overload and overturn situations are determined by finite element analysis. The maximum lateral, vertical and longitudinal force values that can be applied to the head guard and their application forms are determined according to EN ISO 3471 standard. According to the results of deformation under these loads; the head guard was subjected to permanent deformation, but this deformation was observed to have no adverse effect on the safety of the operator of the truck.

References

[1] V. K. Bhagat, P. A. Wankhade, P. P. Gosh, "Development and structural analysis of translation carriage for reach truck," *International Journal of Applied Research in Mechanical Engineering*, 2(2), pp. 93-99, 2012.

[2] I. Doçi and V. Imeri, "Dynamic analysis of forklift during load lifting using modelling and simulations," *International Journal of Current Engineering and Technology*, 3(2), pp. 342-347, 2013.

[3] A. T. Meshram, "Finite element mast assembly of material handling equipment," *International Journal of Technology*, 3(1), pp. 50-55, 2013.

[4] S. B. Rane, H. Shirodkar, P. S. Reddy, "Finite element analysis and optimization of a forklift chassis," *Altair Technology Conference*, 1, pp. 1-6, 2013.

[5] K. Cline, "Failure of a high-capacity forklift fork," *Microscopy Society of America*, 10.S02, pp. 776-777, 2004.

[6] R. Miralbes, H. Malon, L. Castejon, "Design of accessories for the coupling in forklift trucks: Crane gibs and pallet box lock," *Selected Proceedings from the 15th International Congress on Project Engineering*, pp. 233-246, 2011.

[7] G. Stoychev and E. Chankov, "Investigation of dynamic stresses in a forklift truck lifting installation," *Machine Design*, pp. 75-80, 2009.

[8] G. Todorov, M. Ivanov, K. Kamberov, Sv. Stoev, "Design and virtual prototyping of a forklift transmission module," pp. 37-40, 2011.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June2017, pp. 210~216
Available online at:*http://pen.ius.edu.ba*

Determination of Air Permeability Property of Air-Laid Nonwoven Fabrics Using Regression Analyses

H.İbrahim ÇELİK
Gaziantep University, Faculty of Engineering, Textile Engineering Department,
27310 Şehitkamil/Gaziantep, Turkey

Article Info

Article history:

ReceivedMay30th, 2017
Revised June15th, 2017
Accepted June17th, 2017

Keyword:

Air-laid nonwoven
Air permeability
Image processing
Porosity
Regression analysis

ABSTRACT

Air-laid nonwoven fabrics are generally used for hygienic care products such as diaper, adult nappy and sanitary napkins. Air permeability is one of the foremost properties that affect the usage performance of these hygienic care products. In this study, 10 different air-laid nonwoven fabric samples are produced. The porosity ratios of these samples are determined by digital image processing methods. Air permeability of the samples is tested by digital air permeability test device. Then regression analyses were applied to the experimental results using SPSS 21.0 package program. Finally regression equation was obtained for prediction of air permeability by using porosity, thickness and fabric weight.

Corresponding Author:

H.İbrahim ÇELİK
Gaziantep University, Faculty of Engineering,
Textile Engineering Department, 27310
Şehitkamil/ Gaziantep, Turkey.
Email:hcelik@gantep.edu.tr

1. Introduction

Nonwoven fabrics are defined as textile products which are produced as textile sheets from staple or filament fibers and entangled by mechanical, chemical, thermal processes. Products from nonwoven fabrics are widely used in application areas such as hygiene, medical, agriculture, civil, home textile, automotive, filtration, ready-made production, food packaging. With wide variety of application areas and production techniques, nonwoven fabric production rate is increased day by day in Turkey, and the production is carried out in Gaziantep, İstanbul and Çorlu, predominantly [1,2].

In the literature there are many studies that show the effects fabric structural parameters; namely pore size, fiber orientation, fiber type, fabric thickness and fabric weight on fabric performance properties such as air permeability, water permeability, absorption capacity, absorption time, breaking strength and tear strength [3-11]. Aid laid process is a nonwoven web forming process that disperses fibers into a fast moving air stream and condenses them onto a moving screen by means of pressure or vacuum. Air-laid nonwoven fabrics are generally used for hygienic care products such as diaper, adult nappy and sanitary napkins. Air permeability is one of the foremost properties that affect the performance of these hygienic care products. Many researchers investigated the relationship between air permeability and structural features of nonwoven fabrics; namely porosity, fiber diameter, fabric weight, fabric thickness and density [5, 12-18]. Among these structural features, pore size is the determinant parameter for air permeability property. On the other hand, since this type of fabrics have thin structure, determining the pore size properties by using image processing techniques seems possible. In this study, it was intended to use image processing techniques to obtain porosity values of

the fabric samples and then the regression analysis were used to determine the air permeability properties of fabrics by using porosity, fabric weight and fabric thickness as structural parameters.

2. Materials and Methods

2.1. Material

In this study, in order to investigate the relationship between the air permeability and porosity properties of nonwoven fabrics, ten air-laid nonwoven fabric samples produced from the same material (40% viscose, 40% bicomponent, 20% polyethylene) with different thicknesses and weights were randomly selected. The physical properties of these samples were given in Table 1. The nonwoven fabric weight and thickness values were measure in accordance with the standards WSP 130.1(05) [19] and WSP120.6(05) [20] respectively.

Table 1.Properties of air-laid nonwoven fabric samples

Sample Code	Fabric weight (g/m^2)	Thickness (mm)
Nm1	53	0.57
Nm2	53.5	0.57
Nm3	53.5	0.57
Nm4	55	0.7
Nm5	55	0.7
Nm6	54	0.63
Nm7	57	0.74
Nm8	57	0.75
Nm9	55.5	0.67
Nm10	55.5	0.69

All yarn tests were carried out after conditioning the specimens in a standard atmosphere at 20±2 °C temperature and 65±4% relative humidity for 24 hours according to the standard of BS EN ISO 139:2005+A1:2011. Tenacity and elongation measurements of yarn samples were achieved with Uster® Tensorapid-4 according to BS EN ISO 2062:2009. Ten tests were performed in each 4 bobbins and reported values represent the average of those test results.
SPSS 22.0 package program at 95% confidence interval was used for multivariate analysis of variance (MANOVA) in order to determine the significance effect of raw material and blend ratio on yarn tenacity and elongation. Furthermore, Duncan's new multiple range test was provided in order to compare the difference between the means of treatment subgroups of blend ratios in analysis of variance was provided at significance level of 0.05.

2.2. Method

2.2.1. Porosity measurement

In order to make regression analysis, the porosity and air permeability of the fabric samples were measured. All the fabric samples were conditioned in standard atmosphere according to TS EN ISO 139 [21] (65±4% relative humidity and 20±2 0C temperature) for 24 h before the measurements.
Since the nonwoven fabric consists of randomly laid and distributed fibers, space occurs between the fibers. These spaces are called as pores. The porosity of the fabrics can be determined by means of porometer device and image processing application. The porometer device is based on the liquid extrusion through the fabric structure. The image processing method is based on measurement of the light intensity transmitted through the fabric structure. The pixel values of the image frame are assigned according to the light transmission level so that pore regions are seen bright while the regions covered by fibers are seen dark. In this, study the porosity of the fabric samples were determined by using image processing algorithm. The image frames were acquired by using a microscope camera with 60X magnification. Since the nonwoven fabrics have not got a uniform structure, five image frames were acquired from different place of each sample in order to obtain an average porosity value. So, totally 50 sample image frames were processed. The algorithm given in Figure 1 is applied for all five image frames of each sample. The porosity ratio is determined as average of five measurements of each sample. The image frames get in RGB format were convert to 8 bit gray level images. The image frames were the low pass Gaussian filter. The Gaussian filter makes the image frame smoother and removes certain types of noise [22]. The image frame is convolved with the Gaussian function given Equation (1).

$$h_{g(n_1,n_2)} = e^{\frac{-(n_1^2+n_2^2)}{2\sigma^2}} \quad (1)$$

where, $\boldsymbol{n_1}$ and $\boldsymbol{n_2}$ are the locations of the related pixel, $\boldsymbol{\sigma}$ is the variance of neighborhood.

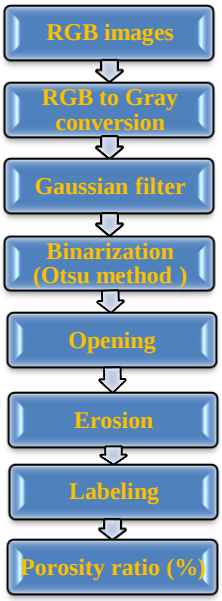
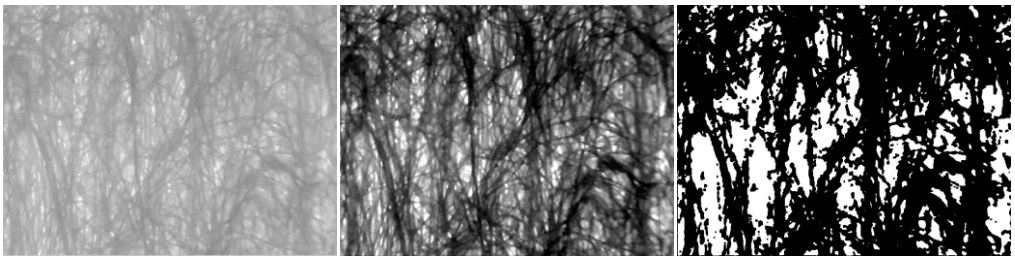
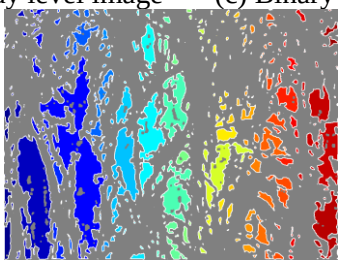


Figure 1. Porosity and pore labeling algorithm

The filtered image is then applied binarization process. Each pixel of the image frame is converted to black or white color according to being below or above threshold level. The threshold level is calculated by using Otsu method [23]. If the pixel value of the image frame is below threshold level, the gray level value of that pixel is allocated as "**0**". Otherwise, it is set as "***1***". The pixel value "***1***" corresponds to white and "**0**" corresponds to black. In the binary image frame, the white regions indicate the pores and the black regions indicate the fibers. In order to clear the area of pores, morphological operations; opening and erosion are applied in sequence. Opening is a morphological operation of erosion followed by dilation with the same structuringelement. The opening operation removes small, isolated objects from the foreground of an image, place them in the background. It smooths the contour of a binary object, breaks the narrow joining regions and eliminates the thin protrusions. In the erosion operation, the center pixel of the structuring element is placed on each foreground pixel value 1. If any of the neighborhood pixels are background pixels value 0, then the foreground pixel is switched to background. Finally, the pore areas (white regions) of the binary are labeled. The application of the algorithm on the air-laid fabric sample is given in Figure 2. The porosity ratio of each air-laid fabric sample is calculated as percentage of white pixels to the whole pixels of the binary image.



(a) RGB image (b) 8 bit Gray level image (c) Binary image



(d) Pore labeled image

Figure 2. Algorithm application on sample image

2.2.2. Porosity measurement

Air permeability is the velocity of an air flow passing perpendicularly through a test specimen under specified conditions of test area, pressure drop (ΔP) and time [24]. Air permeability was measured in accordance with the standard WSP 70.1 (05) [24] using digital air permeability test device at 100 Pa pressure drop and 20 cm² test area. The measurements were repeated ten times for each fabric sample.

3. Results and Discussion

The porosity and air permeability results are given in Table 2 and presented in Figure 3.

Table 2. Air permeability test and porosity measurement results

Sample Code	Air Permeability (mm/s)	Porosity (%)
Nm1	158.6	34.50
Nm2	163	35.63
Nm3	150.1	35.55
Nm4	193.4	38.48
Nm5	193	36.60
Nm6	163.1	34.72
Nm7	183.1	38.35
Nm8	194.7	38.48
Nm9	169.5	36.71
Nm10	176.6	36.21

As expected from the literature knowledge, there is a direct relation between porosity ratio and air permeability performance of the samples except Nm5. This can be attributed to the fact that the air flow occurs between the pores of the nonwoven fabric structure. As the pores between the fibers constitute the fabric structure increase, more open spaces are provided for air flux. On the other hand, less open spaces between the fibers of the nonwoven fabric lead to higher air drag resistance to air flow. The porosity ratio of the nonwoven fabric depends on many different parameters namely, fiber properties, processing conditions, fabric weight and fiber density. Since whole of the samples consists of the same fiber composition, it can be said that the fabric weight and production process conditions affected the porosity property of the samples.

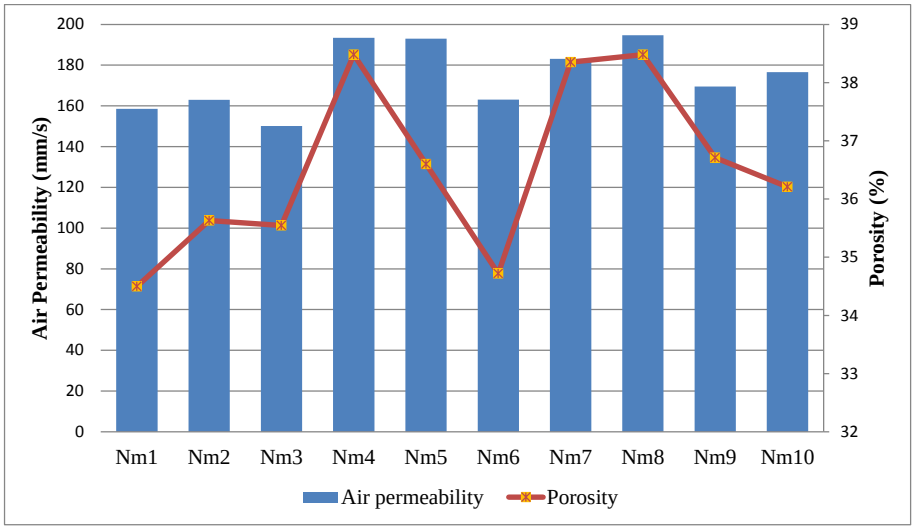


Figure 3. Air permeability and porosity results

On the other hand, fabric thickness also has got effect on the fabric air permeability performance. When the thickness values given in Table 1 are compared with the air permeability results (Figure 4), it can be seen that there is a direct relation with the thickness and air permeability for whole samples.

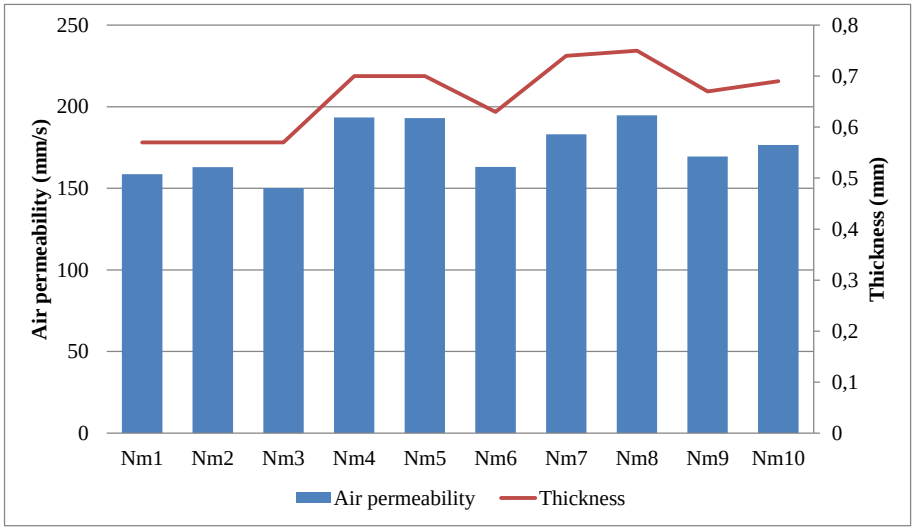


Figure 4. Air permeability results and thickness values

For statistical analyses SPSS 21.0 statistical package program was used. In the first step, correlation analyses were applied to the air permeability, porosity, fabric weight and fabric thickness. The results are given in Table 3. According to correlation analysis, it is seen that there is a strong and positive correlation (r = 0.825) between fabric porosity and air permeability, at 1% significance level. In the view of thickness effect, it can also be said that there is a strong and positive correlation (r = 0.894) between fabric thickness and air permeability, at 1% significance level. The correlation between the fabric weight and air permeability is determined as r=0.752 at 5 % significance level.

The higher thickness causes a longer path for air passage and so the air flow velocity degreases and vice versa. So, negative correlation between thickness and air permeability is proposed. However, according to the analysis results, strong and positive correlation was obtained. This situation can be attributed to the fact that there is also strong and positive correlation (r = 0.849) between fabric thickness and air permeability. As the thickness value increases, the porosity of the samples increases. This situation reveals that porosity increase compensates the diminishing effect of thickness parameter on air permeability. As a result of the correlation results, increased porosity and fabric thickness means high air permeability values for air-laid nonwoven fabric samples.

Table 3. Correlation analysis between air permeability and fabric structural features

		Air permeability	**Porosity**	**Fabric weight**	**Fabric Thickness**
Air permeability	Pearson Correlation	1	0.825**	0.752*	0.894**
	Sig. (2-tailed)		0.003	0.012	0.000
	N	10	10	10	10
Porosity	Pearson Correlation	0.825**	1	0.849**	0.849**
	Sig. (2-tailed)	0.003		0.002	0.002
	N	10	10	10	10
Fabric weight	Pearson Correlation	0.752*	0.849**	1	0.947**
	Sig. (2-tailed)	0.012	0.002		0.000
	N	10	10	10	10
Fabric Thickness	Pearson Correlation	0.894**	0.849**	0.947**	1
	Sig. (2-tailed)	0.000	0.002	0.000	
	N	10	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4. Multiple linear regression analysis for fabric structural features affecting air permeability

Variables	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	453.144	164.962		2.747	0.033
Porosity	4.422	2.305	0.413	1.918	0.103
Thickness	360.830	81.133	1.569	4.447	0.004
Fabric weight	-12.348	4.013	-1.084	-3.077	0.022
a. Dependent Variable: Air permeability					

According to linear regression analysis (Table 4), the regression equation is obtained as below. When three the fabric structure parameters; fabric weight, thickness and porosity are evaluated together in multiple linear regression analysis in terms of effect on the air permeability performance, it can be concluded that the thickness of the air-laid nonwoven fabric has got the most significant effect. The effect of porosity on determining the air permeability performance is less than thickness. The fabric weight has got negative effect on air permeability performance of air-laid nonwoven fabric samples.

$$\text{Air permeability}\,(\text{mm/s}) = 453.144 + 4.422\ \text{porosity}\,(\%) + 360.830\ \text{thickness}\,(\text{mm}) - 12.348\ \text{fabric mass}\,(\text{g/m}^2) \quad (2)$$

4. Conclusion

In this study, the relationship between the air-laid nonwoven fabric structural parameters such as; thickness, weight, porosity and air permeability performance were investigated. Totally, ten air-laid fabrics were selected randomly from the products composed of the same fiber types with same blending ratios. The porosity of the fabric samples were determined by using image processing method. For this aim, an algorithm was developed by applying Gaussian low-pass filter and morphological operation.

As a result of regression analysis, it is concluded that there is a strong and positive correlation between fabric structure parameters; thickness and porosity and air permeability performance of air-laid nonwoven fabrics. There is also a strong and positive correlation between fabric thickness and porosity. So, it can be said that the porosity increase compensates the negative effect of the fabric thickness on the air permeability. Since strong and positive correlation between the air permeability and porosity is obtained as expected from the literature knowledge, the developed image processing algorithm can be considered successful on determining porosity measurement.

According to the multiple regression analysis, the most significant effect on air permeability performance is obtained for fabric thickness parameter. The porosity has got less significant effect than thickness parameter. The fabric weight has got a diminishing effect on the air permeability performance in relation to the multiple regression analysis.

Acknowledgements

Air-laid nonwoven fabric samples used in this study are supplied by Selçuk Group in Gaziantep/Turkey. Author is grateful for firm's cooperation and contribution for this study.

References

[1] E. Çinçik, 2010, "Experimental and statistical analysis of the properties of polyester/viscose blended nonwovens produced by needle punching method," Çukurova University, PhD Thesis, Engineering Faculty, pp.273, 2010.

[2] W.Albrecht, H. Fuchs, W. Kittelmann, *Nonwoven Fabrics*. KGaA, Weinheim; Wiley-VCH,Verlag GmbH & Co, 2003.

[3] A. Rawal, P.V.K Rao, S. Russell, A. Jeganathan, "Effect of fiber orientation on pore size characteristics of nonwoven structures", *Journal of Applied Polymer Science*,vol.118, pp.2668–2673, 2010.

[4] M. Dimassi, L. Koehl, X. Zeng, A. Peruwelz, "Pore network modelling using image processing techniques, application to the nonwoven material", *International Journal of Clothing Science and Technology*, vol.20(3), pp.137-149, 2008.
[5] Ö.B. Berkalp, "Air Permeability & Porosity in Spun-laced Fabrics", *Fibres & Textiles in Eastern Europ*, vol.14(3)-57, pp.81-85, July / September 2006.
[6] M.F. Canbolat, "Structural and mechanical characterization of melt-blown and carded-hydroentangled nonwoven fabrics", *Electronic Journal of Textile Technologies*, vol.5(2), pp.11-17, 2011.
[7] S. Sayeb, M.B. Hassen, F. Sakli, "Study of some nonwoven parameters influence on the absorption kinetics of liquid", *The Open Textile Journal*, vol.3, pp.1-5, 2010.
[8] Jr W.R Goynes, K.H. Pusateri, "Determining fiber orientation in nonwovens by digital quantification of microscopic images," *in Proc. The National Cotton Council Beltwide Cotton Conference*, Jan. 5-9, 2004, San Antonio, TX.p.2784-2795.
[9] A. Rawal, "Structural analysis of pore size distribution of nonwovens", *Journal of the Textile Institute*, vol.101:4, pp.350-359, 2010.
[10] A. Patanaik, R. Anandjiwala, "Some studies on water permeability of nonwoven fabrics", *Textile Research Journal*, vol.79(2), pp.147-153, 2009.
[11] J. Payen, P. Vroman, M. Lewandowski, A. Perwuelz, S. Calle´-Chazelet, D. Thomas, "Influence of fiber diameter, fiber combinations and solid volume fraction on air filtration properties in nonwovens", *Textile Research Journal*, vol. 82(19), pp.1948-1959, 2012.
[12] V. Subramaniam, M. Madhusoothanan, C. R. Debnath, "Air permeability of blended nonwoven fabrics", *Textile Research Journal*, vol.58(11), pp.677-678, 1988.
[13] R. W. Dent, "The air permeability of nonwoven fabrics", *Journal of the Textile Institute*, vol.46(6), pp.220-224, 1976.
[14] H. H.Epps, K. K. Leonas, "Pore size and air permeability of four nonwoven fabrics, *International Nonwovens Journal*, vol.9(2), pp.18-22, 2000.
[15] N. C. Davis, "Factors influencing the air permeability of felt and felt-like structures", *Textile Research Journal*, vol.28(4), pp.318-324, 1958.
[16] V. K. Kothari, A. Newton, "The air permeability of nonwoven fabrics", *Journal of the Textile Institute*, vol.65(8), pp.525-531, 1974.
[17] M. S. Atwal, "Factors affecting the resistance of nonwoven needle-punched fabrics", *Textile Research Journal*, vol.57(10), pp.574-579, 1987.
[18] Y. Yalcin, S. B. Gajanan, "Porosity and barrier properties of polyethylene meltblown nonwovens", T*he Journal of The Textile Institute*, DOI: 10.1080/00405000.2016.1218109, 2016.
[19] WSP 130.1 (05) Standard test method for mass per unit area.
[20] WSP120.6 (05) Standard test method for nonwoven thickness.
[21] TS EN ISO 139 Textiles - Standard atmospheres for conditioning and testing.
[22] 2017, Mathworks website. [Online].
Avaliable: https://www.mathworks.com/help/images/ref/fspecial.html.
[23] R. C. Gonzalez, R. E. Woods, S. L. Eddins, Digital image processing using Matlab" Gatesmark Publishing, LLC, 2009.
[24] WSP 70.1 (05) Standard test method for air permeability of nonwoven materials.

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 217~223
Available online at:http://pen.ius.edu.ba

The Urban Transformation with New Legal Regulations

Fatih TAKTAK[1], Mahir Serhan TEMİZ[1]
[1]Usak University, Faculty of Engineering, Geomatics Engineering Department,

Article Info

Article history:

Received June 01th, 2017
Revised June 16th, 2017
Accepted June 17th, 2017

Keyword:

Urban Transformation
Trents Analysis
Historical Development
Turkey
TOKI

ABSTRACT

All around the world, cities need projects and applications for renewal, transformation, resettlement and improvement due to reasons such as economic reasons, inadequacy in social development, excessive population accumulation, wrong place selection and natural disasters. Many project application examples are available in the world and in our country. They vary in their purpose, form of implementation, organizational patterns and outcomes. In the process of reclaiming troubled areas of cities; a spatial transformation is also being studied at the same time to ensure the social and cultural development.

In this context, the process of urban transformation in our country has been evaluated from the perspective of new legal regulations. In the study, firstly, the urban transformation was very briefly defined and it was focused on the historical development of urban transformation in the Turkey and world. Secondly, Past legal regulations and current legal regulations regard to urban transformation were examined. Lastly, the new legislation was critically discussed. Also the current trends related to urban transformation are investigated.

Corresponding Author:

Fatih Taktak,
Departement of Geomatics Engineering,
UsakUniversity,
Ankara-İzmir Road 8. km, 1Eylul Campus,Usak/Turkey
Email: fatih.taktak@usak.edu.tr

1. Introduction

The urban transformation is the creation of a viable road map as a result of examining the economic, social and spatial characteristics of a region, taking into account urban problems and needs. Urban transformation is a human-focused practice [1]. The aim of urban transformation is to create cities in livable standards. Many problems are encountered in urban transformation applications [2]. These could be the problems arising from the inability to create the corporate structure, problems arising from local governments, lack of staff with sufficient knowledge about the subject, problems caused by the lack of legislation, unsuccessful location selection, issues encountered in informing the projects and financing problem etc., Therefore, in order to ensure rapid and healthy progress of urban transformation, the application regulationwas revised [3], [4].

While trying to sustain intense work agenda in the country, the government took action to remove the obstacle to investors and the regulation on urban transformation was changed [5]. The Council of Ministers will be commissioned to declare a particular area as a 'risky area'. Thus the contractorwill be facilitated by Project developments designed for large areas. If 65 percent of a region is at risk, 100 percent will be covered. In this respect, the objection of individual building owners can be avoided.so that the project will be accelerated. Urban transformation will also be possible in the immovables falling within the scope of the Cultural and Natural Assets Law [6],[7].

2. Material and methods

2.1. The Trends Analysis

Developing data source is internet search queries [8]. Daily, large numbers of users around the world search information via Web search engines. The internet search engine Google provides an internet service, Google Trends (GT), for all internet users to browse the volume of search queries. GT analyzes a fraction of Google web searches to compute how many searches have been done for the terms that users enter, relative to the total number of searches done on Google over time [9]. It is reasonable that some GT regarding specific economic issues can demonstrate the dynamic situation of internet economic-seeking behaviors [10], [11], [12].

GT provides a time series index of the volume of queries which users enter into Google in a given geographic area [13]. The query index is based on *query share*: the total query volume for the search term in question within a particular geographic region divided by the total number of queries in that region during the time period being examined [14], [15]. The maximum query share in the time period specified is normalised to be 100, and the query share at the initial date being examined is normalised to be zero [16],[17]. The Google data are not given in absolute volumes but are indexed to the highest observed search volume, which is set to 100. Consequently, it is not possible to ascertain the frequency of searches that took place at any given time, but only how the searches have changed over time [18], [19].

In this study, the current trends related to urban transformation are investigated. Most relevant trends have been identified. A comparison chart has been obtained with the help of the google trends program. Comparative expressions are given in the graphic. As it can see in the graphic, the most searched phrasewithin one year has been "Housing Development Administration (TOKI)". The lowest call within one year in these trends is the "urban transformation credit" statement. It is understood from the graph, the institution that makes the urban transformation comes to the forefront.

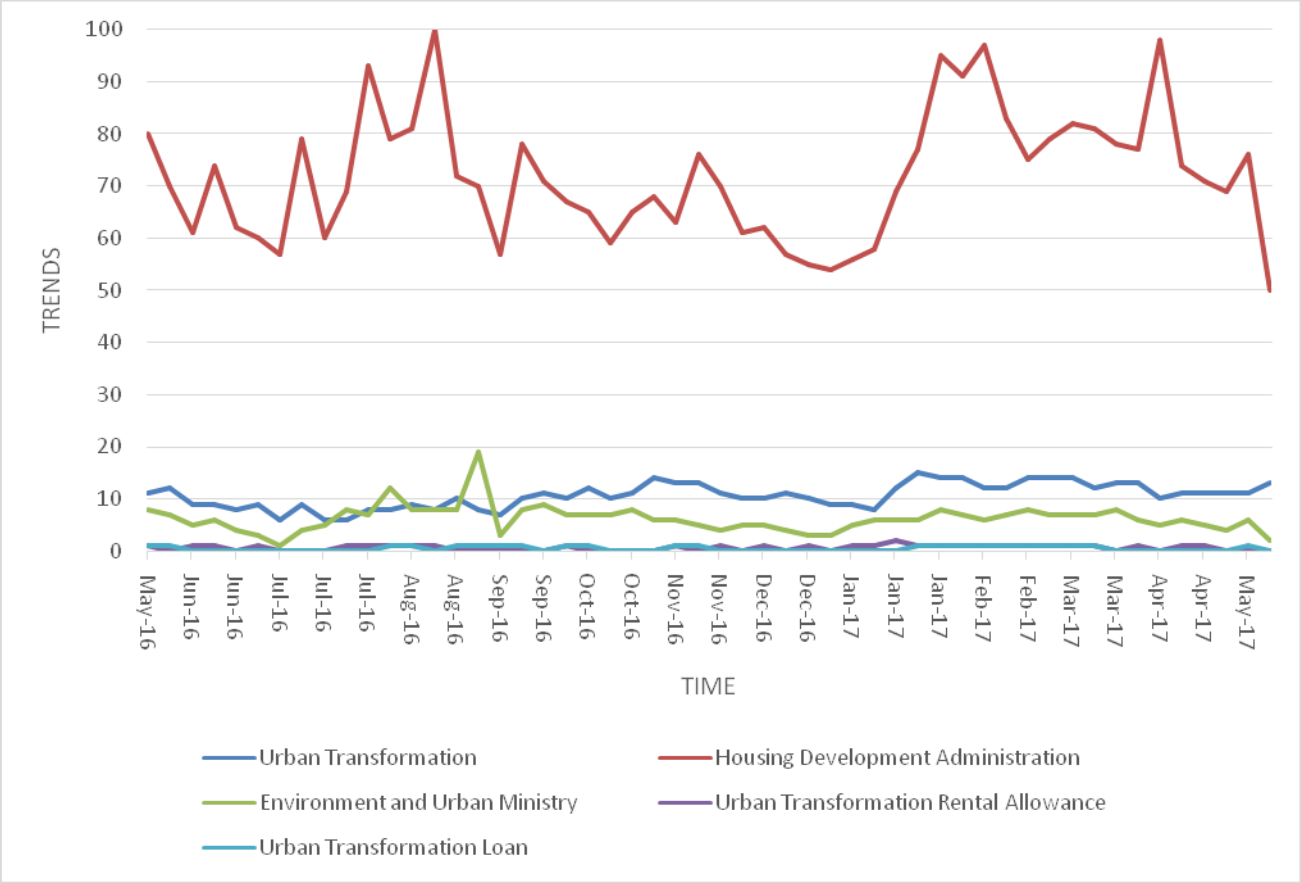


Figure 1. Five trends related to urban transformation are listed.

2.2. The Historical Development of Urban Transformation

Urban transformation applications first appeared in the 19th century as the urban growth movements that took place in Europe, some parts of which have been demolished and reconstructed (urban renewal) [20], [21]. Over time, the political and economic structure of the process of urban transformation has also changed the process of urban planning, from national development towards global integration [22]. For this reason, it is said that the urban transformation applications in the world have different approaches to different periods. Urbanization movements was started in republican period in the country. In the 1950s urbanization was accelerated due to the immigration to the city from the countryside. As the cities are not ready for this situation, the seeds of unhealthy urbanization have been thrown. While the industrial sector was on the rise, there was a decline in the agricultural sector. For this reason, urban spaces need to be transformed and renewed. Almost every province in our country has places that lack technical infrastructure and other equipment that do not conform to regular urban development.

Due to such matters, regular legal regulations have been made. From past to present, the legal regulations related to urban transformation are stated in table1 [23].

Table 1. Legislation Regarding Urban Renewal in the Past to Today.

Legislation Regarding Urban Renewal in the Past to Today

Law No Date	Law Name	Purpose
Law No:7367 July 21, 1959	Law on Land and Ares from Transferable to Municipalities	The main purpose of the law are to use these land for the production of urban land and Free transfer to municipalities of State-owned land. By law, Law No. 6188, the state-owned lands and the transfer-related provisions of the other related lands are abolished.
Law No:634 June 23, 1965	Floor Ownership Law	Independent property rights may be established by the owners or joint owners of the real estate on the basis of the provisions of this Act on the completed buildings, apartments, business offices, shops, warehouses, warehouses, etc. which are individually and individually available. Easement rights may be established in accordance with the provisions of this Law by the land owners or joint owners of the land on the basis of the property of the floor which will be overcome after the construction is completed.
Law No:775 July 20, 1966	Slums Act	Refurbishment of existing slums, liquidation, preventing the re-construction of squatter and the provisions of this Law shall apply to the measures to be taken for these purposes
Law No:1164 April 29, 1969	Land Production and about the Law	Purpose of this Law; Buying and selling to prevent excessive price increases of the Land; Housing, industry, education, health and tourism investments and public facilities.
Law No:2985 March 02, 1984	Mass Housing Law	Meeting the housing needs, arranging the procedures and principles that will be applied to those who build houses, development of industrial construction techniques and tools and equipment suitable for the materials of the country and support be made by the State. It is subject to the provisions of this Law.
Law No:2981 Feb. 24, 1984	Zoning amnesty law	Purpose of this Law; Arrangements to be implemented in respect of all buildings constructed in contradiction to the legislation of Zoning and shantytown and determine the principles of application, determination, evaluation, implementation and announcement of these transactions and other relevant matters.
Law No:3194 May 03, 1985	Zoning law	This law is designed to provide settlement places and structures of these places in accordance with plan, science, health and environmental conditions
Law No:5104 March 04, 2004	North Ankara Entrance Urban Transformation Project Law	Purpose of this Law; North Ankara entrance and surrounding areas is to create a project of urban transformation. So; the development of physical condition and environmental view in Ankara, beautification, provision of a healthy settlement system and increase the level of urban life.
Law No:5216 July 10, 2004	Metropolitan Municipality Law	The purpose of this law is to regulated the legal status of the administration of the metropolitan municipality and to ensured efficient, efficient and harmonious implementation of the services
Law No:5226 July 14, 2004	Conservation of Cultural and Natural Assets	Cultural and Natural Heritage Protection Act was amended to certain reagents.
Law No:5273 Dec. 08, 2004	Law on the Removal of the General Directorate of the Land Office	The General Directorate of Land Office was removed together with the organization.
Law No:5302 Feb. 22, 2005	Special Provincial Administration Law	Purpose of this Law is to regulate the establishment, Organs, management, duties, powers and responsibilities and working principles and principles of Special provincial administration
Law No:5393 July 03, 2005	Municipal Law	The purpose of this law is to regulate the procedures and principles of the establishment, the organs, the administration, the duties, authorities and responsibilities of the municipality.
Law No:5998 June 17, 2010	Law Amending the Law on Municipalities	Municipality, with the decision of the municipal council can apply urban renewal and development projects that to create residential areas, industrial areas, commercial areas, technology parks, public service areas, recreational areas and all kinds of social facilities areas, rebuilding and restoring old parts of the city, in order to protect the historical and cultural

		heritage of the city or to take measures against earthquake risk
Law No:6306 May 16, 2012	Law on Converting of Areas Under Disaster Risk	Purpose of this Law, In areas where there are risky structures outside these areas with areas under disaster risk is to determine the principles and procedures for improvement, liquidation and renewal in order to constitute healthy and safe living environments in accordance with science and art norms and standards.
Law No:6360 Dec. 06, 2012	thirteen provinces also and with Twenty-Six County establishment, Law on the Amendment of Decrees on Certain Laws and Laws	The metropolitan municipality was established with the same name as the provincial property boundaries in Aydın, Balıkesir, Denizli, Hatay, Malatya, Manisa, Kahramanmaraş, Mardin, Muğla, Tekirdağ, Trabzon, Şanlıurfa and Van and these municipalities' municipalities have been transformed into the metropolitan municipality.
Law No:6360 Nov. 12, 2012	fourteen provinces also and with Twenty-seven County establishment, Law on the Amendment of Decrees on Certain Laws and Laws	Law No. 6360, adopted on 12 November 2012 was amended on 06 December 2012; Ten Fourteen Metropolitan Municipalities and the Establishment of the Twenty-Seven Districts Some Law and the Law on the Amendment of the Decrees in the Law has become law.
Law No:6306 Oct. 27, 2016	Regulation of Law on Converting of Areas Under Disaster Risk	Due to the size of the problems experienced during the urban transformation process, it can be seen that there are almost serious and process-accelerating changes in the regulation and an urban transformation process almost at the jet speed.

2.3. Online Submission Change of Urban Transformatıon Regulatıon and Improvements

1. **If a deterioration occurs in 65% of one or more of these criteria, these regions can now be declared as Risky Areas**, in the areas where infrastructure and superstructure have been damaged, contrary to the zoning legislation, inadequate planning and infrastructure services, in order to avoid the cancellation of the Council of State in risky areas.
2. The section regarding the need to be at least 15.000 m^2 in risky area advertising has been removed from the obligation. **Thus, without any limitation of** m^2**, the risky areaadvertising in each region can be declared provided that it carries other criteria.**
3. The personnel who will work in establishments that will determine risky structures are entitled to issue certificates in the institutions and organizations that will be determined by the Ministry for the necessity of obtaining certificates from the Ministry of Environment and Urbanization.The certificate exemption granted to universities is limited to academic staff only. **At least one civil engineer will operated in the licensed institutions that will perform risky structure detection.**
4. The principles for risky structure determination are clarified and will be used for buildings and structures for people to sit, work, play or rest or worship, and structures for the protection of animals and their property. Buildings that are under construction and that are not resident, damaged or unstable due to deformation or static will not be subject to risky structure determination.
5. To be in risky structure determination application; Petition, identity photocopy and current title deeds status certificate will be required. Land register is not enough with the old state. The current title deeds status document must be obtained from the relevant place and submitted to the licensed company.
6. The big problem in the courts has been resolved in the owner's dead real estate. In the apartments that are trying to get along with the requests for intervention, a very big problem has been solved by granting the authority to assign a seatkeeper to the Ministry.
7. In the immovables falling within the scope of the Culture and Natural Assets Law, the application of urban transformation will now be possible. Here, the owner or one of the owners of the building will be present and after the risky structure is determined, the application will be decided with the decision to be taken from the establishment.
8. Evictions which are not made to tenants and limited beneficiaries are no longer valid. The tenant or limited rights owner must be notified about the evacuation periods of municipalities. If this is not done in the previous regulation, which is not sanctioned, the periods will not start. So if you have a tenant, you should give him a notary etc. by roads. If you have not sent a notice of eviction, the time will be restarted by the municipality.

At the end of the evacuation periods, electricity, water and natural gas services have to be stopped. No municipalities will not be able to refrain from writing this article again: I will not do any electricity, water or gas administration process.

9. With regard to buildings that have not been demolished at the end of the current evacuation periods, the expectation of the agreement of the owners is now completely abolished.2 month audits shall be carried out and the buildings which are not demolished shall be demolished by law enforcement support and civilian authority due to Disaster Relief.The situation in the previous regulation gave rise to months and years of elongation due to the fact that no agreement was reached with 2/3 of apartments or sites.The building which can no longer be demolished by supervision made in buildings or blocks shall be immediately demolished by the administration.
10. At risky areas or risky structures, decisions can be made by 2/3 without destroying the structure. Again with the decision of 2/3 before the structure was destroyed; It will be allowed to The zoning application in zoning island.
11. Blocked structures existing in a parcel are separated from structures that have not been identified as risky structures. A commentary will be put on the buildings where risky structures are determined. In practice the parcel is not over the whole, the risky structure will be decided by a majority of 2/3 of the total number of building owners.
12. If the floor easement or floor ownership facilities are requested on behalf of the rights owners; It may be made by the Ministry, TOKI or Administration. In this case, Independent section on the rights owners should definitely be shown in the project.
13. **The requirement that the building is now demolished has been removed in order to sell a 1/3 share of the land which is not included in the decision with 2/3.So that making decision with 2/3 and submitting 15-day warning notice to those who do not participate in the meeting has been made sufficient.One of the biggest problems in urban transformation has thus been solved.Due to the evacuation distress and contractor's obligation to pay rent,A solution has been found to delay the demolition request.An auction sale will be possible without demolition.**
14. After sales with auction, Cancellation of contract or contract documents, resale,That is, the process of prolonging the sale by repeating the sale; It is completely closed.Accordingly, the land owner who declares that he will sign the contract by participating in the tender; If you cancel any of the contract or its annexes after signing the contract, you will be sold to the highest bidder in the 90-day period and to the others in turn if you do not accept it.In this case, the sale has been turned into a single transaction and the possibility of second or third sales has ceased.
15. Rental allowance is determined as 36 months in risky areas, 18 months at risky structures. By changing the previously restricted state; the owners, tenants or limited rights holders can be given rental allowance for all the structures that they have or have fallen under the law. The rent allowance will be accepted as valid if it is requested within 1 year from the date of evacuation.
16. The tax fees and fee exemption paid to the municipalities have been removed. Municipalities will continue to charge fees [24].

3. Conclusions

Unplanned or contrary to the provisions of the plan,constructionsare the biggest obstacles in front of the regular, healthy and aesthetic urbanization.The struggle with the illegal structures is one of the basic tasks of the administration. Due to the weaknesses and hesitations that arise in the struggle against illegal construction,Infrastructures and superstructure have led to the emergence of problematic cities.It is inevitable that cities that are unplanned, irregular and irregularly structured can not fulfill the expected function of themselves, but also cause risks in the safety of life and property of the people who live there.In the practice of urban transformation and in the struggle against disaster risk, the administration has the power to directly influence and create pressure on rights and freedoms.It should be essential to be moderate in the use of the authority recognized by the competent authority.If it is possible to transform without ending the property right, the practice must be carried out in this framework.The process of urban transformation should be as short as possible.The amendment of the regulation is also aimed for this purpose. It is considered necessary to create a sustainable urban model with the participation of the transformation projects, all other institutions and public. Implementation strategies must be defined before the transformation process begins.

Rather than creating irresponsibility chains through piecemeal regulation, solutions must be produced under a single set of laws; and socio-economic and development plans must be displayed on terms to be addressed seriously. In addition, the new legal regulations have not yet fully resolved the ownership problems. There is

still a problem in the implementation of urban transformation and a need to reorganize property rights.It should not be forgotten that the main purpose is to increase the quality of life. They are missing in our laws and should be supported by new legal regulations.

In this study, firstly, terms related to the general trend in the country's urban transformation were compared among themselves. The "TOKI (Housing Development Administration)" term that stands out among the terms was determined by the google trends program. Then the issue of urban transformation, legal and application dimensions were discussed in general terms. In the last part of the study, the legal grounds related to urban transformation and the criticisms directed to the practices were emphasized.

References

[1] Montgomery, M. R., "The urban transformation of the developing world," *science, 319*(5864), 761-764, 2008.

[2] Tasan-Kok, T., "Analysing Path Dependence to Understand Divergence: Investigating Hybrid Neo-Liberal Urban Transformation Processes in Turkey," *European Planning Studies*, vol. 23, no. 11, 02 Nov. 2015, p. 2184-2209, 2015.

[3] Tas, N. and Tas, M., "Determining of the Local Housing Identity in Urban Transformation Areas under Disaster Risk: Bursa, Turkey." *Natural Hazards*, vol. 75, no. 1, n.d., pp. 119-139, 2017.

[4] Demirli, M., Ultav, Z., and Demirtas-Milz, N., "A socio-spatial analysis of urban transformation at a neighborhood scale: The case of the relocation of Kadifekale inhabitants to TOKI Uzundere in Izmir", *Cities*, 48, pp. 140-159, 2017.

[5] Cahantimur, A., Ozturk, R., and Ozturk, A., "Securing land for urban transformation through sustainable brownfield regeneration - the case of Eskisehir, Turkey." *Environment And Urbanization* 22, no. 1 (n.d.): 241-258, 2010.

[6] Çağla, H. and Inam Ş., "Yerel Yönetimler Öncülüğünde Yapılan Kentsel Yenilenme Proje Uygulamaları Üzerine Bir İnceleme", TMMBO Harita ve Kadastro Mühendisleri Odası, 12. Türkiye Harita Bilimsel ve Teknik Kurultayı, 11-15 Mayıs, Ankara, 2009.

[7] Ayhan, F., "Kentsel Dönüşüm Hukuku (Kentsel Dönüşüm Kavramı Ve Tarihsel Gelişimi*)," İstanbul Üniversitesi S.S.ONAR İdare Hukuku ve İlimleri Araştırma ve Uygulama Merkezi Yayınları*, s: 87, 2013.

[8] Choi, H., and Varian, H. "Predicting the present with Google Trends." *Economic Record* 88. s1: 2-9, 2012.

[9] Carriere-Swallow, Y. and Labbe F., "Nowcasting with google trends in an emerging market." *Journal of Forecasting*, DOI:10.1002/for.1252, 2011.

[10] Valdivia, A. and Monge-Corella, S., "Diseases tracked by using Google trends, Spain,". *Emerg Infect Dis*, *16*(1), 168, 2010.

[11] Troumbis, A.Y., "Declining Google Trends of public interest in biodiversity: semantics, statistics or traceability of changing priorities?," *Biodiversity And Conservation*: 1-11, 2017.

[12] Pelat, C., Turbelin, C., Bar-Hen, A., Flahault, A., and Valleron, A. J., "More diseases tracked by using Google Trends." *Emerging infectious diseases* 15.8: 1327-8, 2009.

[13] Carrière- Swallow, Y., and Labbé, F., "Nowcasting with Google Trends in an emerging market." *Journal of Forecasting* 32.4: 289-298, 2013.

[14] Kristoufek, L., " Can Google Trends search queries contribute to risk diversification? " *ArXiv önizleme arXiv:* 1310.1444, 2013.

[15] Valdivia, A., and Monge-Corella, S., "Diseases tracked by using Google trends, Spain." *Emerg Infect Dis* 16.1: 168, 2010.

[16] Zhou, X., Ye, J. and Feng, Y., "Tuberculosis surveillance by analyzing Google trends." *IEEE Transactions on Biomedical Engineering* 58.8: 2247-2254, 2011.

[17] Yılmaz, H. H., Yazıhan, N., Tunca, D., Sevinç, A., Olcayto, E. Ö., Özgül, N., and Tuncer, M., "Cancer trends and incidence and mortality patterns in Turkey." *Japanese journal of clinical oncology* 41.1: 10-16, 2011.

[18] Esbah, H., "Land use trends during rapid urbanization of the city of Aydin, Turkey." *Environmental Management* 39.4: 443-459, 2007.

[19] Chadwick, M. G., and Sengül, G., "Nowcasting the Unemployment Rate in Turkey: Let's Ask Google." *Central Bank Review* 15.3: 15, 2015.

[20] Geymen, A.,"On the Use of Terrestrial Laser Scanners to Facilitate Project Studies of Urban Transformation in the Historic Peninsula of the Metropolitan Area of Istanbul." *Lasers In Engineering (Old City Publishing)* 20, no. 3/4: 225-239, 2010.

[21] Güzey, Ö., "The Last Round in Restructuring the City: Urban Regeneration Becomes a State Policy of Disaster Prevention in Turkey." *Cities*, vol. 50, 01 Feb., pp. 40-53, 2016.

[22] Ozus, E., Turk, S. S. and Dokmeci, V. "Urban Restructuring of Istanbul." *European Planning Studies*, vol. 19, no. 2, Feb., pp. 331-356, 2011.

[23] Kampüsü, B., "Yeni Yasal Düzenlemelerle Kentsel Dönüşüm." *Planning* 26.1: 51-64, 2016.

[24] Implementing Regulation of the Law No. 6306, http://www.csb.gov.tr/gm/altyapi/index.php?Sayfa=sayfa&Tur=webmenu&Id=295

BIBLIOGRAPHY OF AUTHORS

Asst. Prof. Fatih TAKTAK, born in 1978. He graduated in 1996 as Dipl.-Ing. in Geodesy and Photogrammetry Engineering at Selcuk University. He obtained his MsC degree in 2005 at Kocatepe University. He obtained his Ph.D. degree in 2013 at Yildiz Technical University. He is since 2014, Asst. Prof. of Engineering Faculty, Usak University. He is currentley working on Land Management and urban transformation.

Undergraduate:Ondokuz Mayis University / 2001, Master Degree:Ondokuz Mayis University / 2005, Doctorate:Istanbul Technical University / 2012, Assistant Professor:UsakUniversity / 2003, **Expertise:** Photogrammetry,Image Processing

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June2017, pp. 224~230
Available online at:http://pen.ius.edu.ba

Production of Dye from Green and Brown Walnut Shells for Leather Coloration

Neslihan Doğan-Sağlamtimur[1], Ersen Turaç[2], Ruhsar Arabacıoğlu[1], Tuğba Çivioğlu[1]
[1]Department of Environmental Engineering,Omer Halisdemir University, Nigde, 51240, Turkey
[2]Department of Chemistry, Omer HalisdemirUniversity,Nigde, 51240, Turkey

Article Info

Article history:

Received June 13rd, 2017
Revised June 15th, 2017
Accepted June 17th, 2017

Keyword:

Dye
Environment
Leather
Reuse
Walnut
Waste

ABSTRACT

Nowadays, it is observed that there is an increasing approach to the use of natural substances instead of synthetic ones. As the synthetic materials and products are more complex in comparison to natural substances, it will take a long time to complete their natural cycles and return to nature, thus, causing a lot of environmental pollution.Green and brown shells of walnuts that are not only valuable crops but also important components of the Mediterranean dietare by-products of the walnut production, having scarce use (especially green shell). Thus, using shells as a source of dye will increase the value of the walnut production, as well as offering utilization for a by-product, which is produced in large quantities. The purpose of this study is to produce dye from wastegreen and brown walnut shells, compare quality of these dyesand apply themseparately in untreated leather. Before chemical processes, the walnut shells were chopped in a grinding mill. They were dried in an oven toeliminate the humidity and extracted inSoxhlet apparatus by using ethanol solution. Then,the ethanol solution was evaporated in controlled way and the produced dyes weremordanted by using potassium aluminium sulphate (PAS). The dyes were analysed by TLC and UV-Vis, whereas dyed leathers were analysed by colorfastness test. The present study showed that brown walnut shell dye having higher color values was better for yield, dye penetration and fastness properties compared to green walnut shell dye.Luminous effect was observed when these dyes were applied in leather. It is interesting, uncommon and economically valuable for leather industry.This study would be a positive step to meet the need of leather industry in Turkey and a good example for cleaner production.

Corresponding Author:

Neslihan Doğan-Sağlamtimur,
Department of Environmental Engineering,
Omer Halisdemir University,
Nigde, 51240, Turkey.
Email: neslihandogansaglamtimur@gmail.com

1. Introduction

Nuts are important components of the Mediterranean diet. *Juglans regia Linn (Juglandaceae),* which is known as the walnut, is a tall deciduous tree of about 20 meters-in-length [1]. Walnuts are widely distributed all over the world, and in Turkey, these species are common along the country. The Juglans genus (family *Juglandaceae*) comprises several species and spreadsall over the world. The walnut tree (*Juglans regia L.*) is its well-known member, constituting an important species of deciduous trees found primarily in temperate areas. It is cultivated commercially throughout southern Europe, northern Africa, eastern Asia, United States and western South America. In Turkey, walnut trees can be found all over the country, being the nuts very popular and largely consumed as part of the Mediterranean diet. Walnut green shell is a by-product of the

walnut production, being formed in large amounts. Probably due to its scarce utilization, this matrix is very little studied [2].

Our world is reaching to new high horizons with the growth of mankind, society, science and technology but the cost which we are paying or will pay in near future is surely going to be too high. Among the consequences of this rapid growth is environmental disorder with a big pollution problem [3]. The pollution control is one of the prime concerns of society today. Untreated or partially-treated wastewaters including dyes from various industrial effluents into natural ecosystems pose a serious problem to the environment. One of the important class of the pollutants is dyes, and once they enter the water it is no longer good and sometimes difficult to treat as the dyes have a synthetic origin and a complex molecular structure which makes them more stable and difficult to be bio-degraded [4, 5]. Synthetic dyes have complex aromatic structures which are widely used in the industries such as textiles, rubber, paper, plastics, food, and cosmetics to color their products [6]. These dyes are harmful to fauna, flora, and some of dyes and their products have a mutagenic or carcinogenic influence on human beings [7]. Even at low concentrations, dyes could be highly noticeable, and can cause an aesthetic pollution and disturbance to the ecosystem and water sources [8]. Hence, removal of these compounds from the effluents is necessary.

The worldwide use of walnut green leaves and shells for natural dyeing of textiles has ancient roots. During the last years, an increased interest was noted for the use of natural dyes in textile dyeing process. Recent studies drew the specialists' attention since natural dyes were found to have, besides coloring properties, good insecticidal effects-thus helping to the fiber protection [9]. The walnut shell that is used as a coloring agent belongs to the group of nutshells, a class of highly insoluble species. It has antibacterial properties.

Natural dyes are mostly eco-friendly, renewable, biodegradable, less toxic and less allergenic as compared to synthetic dyes [10]. Still the use of natural dyes involves some disadvantages such as requirement of large amounts of plant material, limited success in dyeing synthetic materials, need for the use of mordants and poor light stability [11]. Overcoming these disadvantages, the aim of this study is to obtain natural dye from waste green and brown walnut (*Juglans regia* L.) shells for dye and leather industry.In this study, the leather coloration was performed by the dyes produced from green walnut shell (GWS) and brown walnut shell (BWS).

This paper introduces an analytical method for identifying the dyeobtained from these walnut shells which is based on the extraction of colorant from them through a solvent using Soxhlet apparatus. In this study, dyeability of leather with walnut shell extracts have been investigated. Untreated leathers were dyed with dyes produced from GWS and BWS. Mordant wasused as to its effectiveness to changethe color of the leather. In the study, it was gathered much information on the chemical composition of the dyes produced fromGWSand BWSby using series of analysis.

2. Material and Methods

In general, green and brown walnutsareharvested in September when they seem to be richest in active principles. In the present work, GWS and BWS (Photo 1) from one walnut cultivar (Kaman) grown in Turkey, were studied, regarding their dyeing activities.

Photo 1. GWS and BWS

The chemicals used in this study were analytically graded and provided by Merck Co. Following experimental steps were performed toproduce natural dye from GWS and BWS: (a) cracking, shelling, chopping and grinding of these shells (by using grinding mill) to increase the contact surface and decrease the sample size,(b) eliminating humidity from the shells after dried in oven, (c) extraction processing with Soxhlet extraction method by using ethanol solution, (d) evaporating this ethanol solution in controlled way, and (e) mordanting of obtained dyes by using potassium aluminium sulphate (PAS).

At first, we employed the Soxhlet apparatus to extract colorants from GWS and BWS byethanol solvent. The dissolved colorants in ethanol were collected by means of rotary evaporator. In this study, 100% untreated leather was employed as the main substrate.

Experimental details were as follows

Extraction- 20 g GWS or BWS, 50 mL ethanol, 300 mL DDW, 110 °C, 4 hr.

Mordanting- 25 °C, 4 hr.

Dyeing- 20 g sodium carbonate, 50 g sodium chloride, 10-20 mL dye, 60 °C, 4 hr.

Thin layer chromatography (TLC)

TLC method by aluminum sheet, silicagel 60f254 was done. For separation of the components from the obtained extract, 0.5 g was diluted with 1 ml benzene; methanol-chloroform 1:1 was used as mobile phase on 250 mm silicagel plate; eight spots were put at the starting line. The dye was quickly released from the starting line leading to a single strong brown spot. The compound type can be identified by mean of retardation factor value, R_f .

$R_f = h_A/h_S$ where h_A was the average distance from the start to the middle of the spots and h_S the distance from the start line to the solvent end line.

Colorfastness

Color characteristics of dyed samples were determined with a Premier Colourscan SS 6200A spectrophotometer using illuminant D65 and 10°standard observer in terms of CIELab values (L*, a*, b*) and color strength (Table 1). Colorfastness to washing/laundering (machine), water, perspiration, light and rubbing tests were conducted according to ISO Standards (15702,11642, 11641, 105-B02 and 11640, respectively) (Table 2) [12-16].

Fastness of the color of leather to machine washing [12] is the resistance to washing under domestic machine laundering in water. In washing leather, not only changes in color can occur in the leather, but colored substances may bleed from it and may stain adjacent textile materials. In "Colorfastness of Leather to Machine Washing Method", the samples of dyed leather in contact with undyed textiles, e.g. multi-fibre strips or wool and cotton, are agitated in a solution of a standard wash detergent (4g/L ECE Colour Fastness Test Detergent 77) for 30 min at 40°C. The samples are rinsed and dried.The change in color of the leather specimen is compared with the original leather sample and the staining of the textiles are assessed with standard Grey Scales.

The colorfastness of leather to water [13] is the resistance to the prolonged action of water. Pre-wetted pieces of wool (W) and cotton (C), or multi-fibre fabric strips, are placed on the test surface of the dyed leather sample, which has been thoroughly wet out in water. The composite specimen is then placed between glass plates under pressure for 3 hours at 37 °C. The specimen and the textile are dried. The change in color of the leather specimen is compared with the original leather sample and of the textile are assessed with standard Grey Scales.

By fastness of color of leather to perspiration [14] is meant its resistance to the prolonged action of an artifical perspiration solution. Samples of leather and textile fabrics, e.g. a multi-fibre strip or pieces of W and C, are thoroughly wetted out separately in an artifical perspiration solution. The textiles are placed on the side of the leather specimen to be tested and the composite specimen is then placed between glass plates under pressure for 3 hours at 37°C. The specimen and the textile pieces are dried. The change in color of the dyed leather is compared with the original leather sample and the staining of the textiles are assessed with the standard Grey Scales.

Colorfastness of Leather to Light: Xenon Lamp Method [15] is intended to determine the resistance of the color of leather to the action of a standard artificial light source. The Xenon lamp has an emission wavelength profile close to daylight. The side to be tested of the leather sample is exposed to light from a Xenon Lamp, under controlled conditions, along with eight blue dyed wool standards (blue scale). The light fastness is assessed by comparing the fading of the leather with the fading of the blue standards. The fading is typically made in 2 exposure times to better assist the evaluation. The exposure time can be varied depending on the

lamp intensity and the blue scale level required. To measure up to a maximum blue scale level 3 an exposure of 20h and 80h (as below) is often sufficient for a quick checking of the light fastness rating.
Colorfastness of Leather to Rubbing Method [16] is intended to determine the transfer of color and the behaviour of the surface of a leather on rubbing with an undyed wool felt.The side of leather to be tested is rubbed with pieces of standard wool felt under a given pressure with a given number of forward and backward motions. The wool felts can be either dry, wetted out in water or wetted with a solution of artifical perspiration at pH 8.The change in color of the felt and of the leather are assessed with a standard Grey Scales.

Ultraviolet and visible spectroscopy (UV-Vis)

UV-Vis spectroscopic analyses were performed on a Shimadzu UV-160A spectrophotometer.

3. Results and Discussion

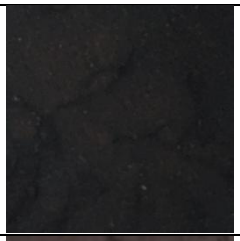
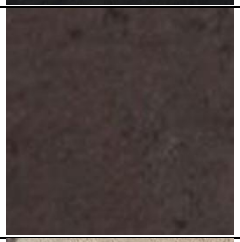
TLC

In TLC, the compound type can be identified by means of retardation factor value, indicating R_f (h_A/h_S). In this study, calculated R_f values of dyes produced from GWS and BWS were found to be 0.5625 and 0.6775.

Colorfastness

There were 2 dyes x 1 mordant type x 3 replications for colorfastness to light testing. Mordanting has an important effect not only on colorimetric properties but also on leather shades. Brown color and color shades were obtained in the presence of mordant (PAS) (Table 1).

Table 1. Dyes Exposed to Colorfastness to Light Test

Material	Color Palette/ Color Swatch	L	a	b	Red	Green	Blue	H	S	B
GWS dye		12	0	0	32	32	32	0	0	13
BWS dye		24	6	3	68	54	53	4	22	27
Control		75	3	12	196	181	162	34	17	77

H: Hue, S: Saturation, B: Brightness

Mordanted dyesproduced from GWS and BWS were tested for colorfastness to light in accordance with related test method to obtain CIELab ratings, determining the specific color coordinates L*a*b*. When looking at the effect of exposure, all dyes had significant effect for L* (lightness) when exposed to 24 hours of light. L* showed that leather dyed with GWS was darker than leather dyed with BWS after lightfastness testing. Leathers dyed with GWS and BWS had significant difference when looking at the L* coordinate. a* coordinates were not similar after light exposure for dyed leathers. Leathers dyed with GWS and BWS were dark gray and brown (b*), and control sample was beige after lightfastness testing (Table 1).
Results of colorfastness to washing/laundering, water, perspiration, light andrubbing tests were given in Table 2 and 3. The change in color of the dyed leathersis compared with the original leather sample and the staining of the textiles are assessed with the standard Grey Scales that are used for assessing changes in color of leather in colorfastness tests.The scale consists of nine pairs of grey color chips each representing a visual difference

and contrast. The fastness rating goes step-wise fromNote 5=no visual change (best rating)to Note 1=a large visual change (worst rating).

Colorfastness (washing/laundering, water, perspiration, light and rubbing fastness) test results for leather sample dyed with GWSand control leather sample were the same (gray scale rating of 3 to 5), meaning that there was no change between them. However,colorfastness test results of leather dyed withBWSwere different (gray scale rating of 2 to 4+) (Table 2, 3). Leather dyed with BWS performed better than the control and leather dyed with GWS when tested for light fastness (Table 2).

Table 2. Colorfastness (washing/laundering, water and perspiration fastness) test results for leather samples dyed with GWS and BWS

Material	**Washing/laundering fastness**							**Water fastness**							**Perspiration fastness**						
	W	**A**	**P**	**N**	**C**	**A**	**Color change**	**W**	**A**	**P**	**N**	**C**	**A**	**Color change**	**W**	**A**	**P**	**N**	**C**	**A**	**Color change**
Leather dyed with GWS	4/5	4/5	4/5	4/5	4/5	4/5	3	4/5	4/5	4/5	4/5	4/5	4/5	4	4/5	4/5	4/5	4/5	4/5	4/5	4
Leather dyed with BWS	4+	4+	4+	3/4	2/3	4+	2-3	4+	4+	4+	3/4	3/4	4+	4	4+	4+	4+	3/4	3/4	4+	4
Control	4/5	4/5	4/5	4/5	4/5	4/5	3	4/5	4/5	4/5	4/5	4/5	4/5	4	4/5	4/5	4/5	4/5	4/5	4/5	4

W: Wool, A: Acrylic, P: Polyester, N: Nylon, A: Acetate

Table 3. Colorfastness (light and rubbing fastness) test results for leathers dyed with GWS and BWS

Material	**Light fastness**	**Rubbing fastness**	
		Dry	**Wet**
Leather dyed with GWS	2	4+	3/4
Leather dyed with BWS	3-4	3/4	2
Control leather	2	4+	3/4

UV-Vis

The resulting spectra from UV-Vis analysis of the dyes at one concentration (30 μg/mL) are shown in Figure

1. The peaks appear around λ=667, 270 and 632 nm for dye produced from GWSand 303 and 910 nm wavelengths for dye produced from BWS.

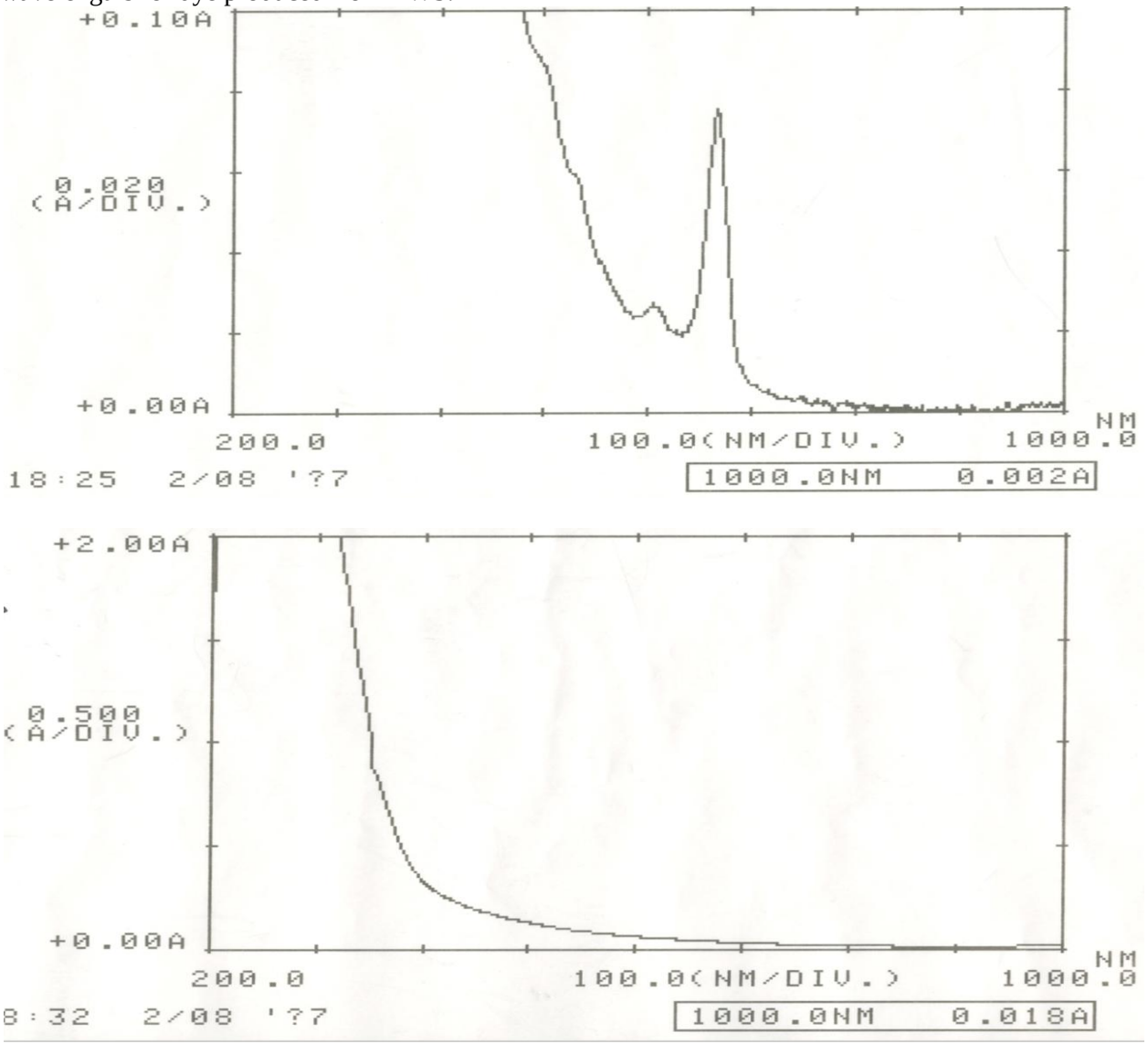


Figure 1. UV-Vis spectra of the dyesproduced from GWS (above) and BWS (below)

4. Conclusions

Natural dyes are excellent for their soft and lustrous pastel colors. They give harmonizing colors. Sometimes it is possible to obtain some brilliant colors from natural dyes using mordants. Dyes of natural origin are great for color experimentation as any variation in the concentration of dye, mordant, types of water, soil and climate give variation in colors. Moreover, using shells as a source of dye will increase the value of the walnut production, as well as offering utilization for a by-product, which is produced in large quantities. After many experiments, in this research, by adding 50 mL ethanol and 300 mL DDW at 110 °C Soxhlet extraction in 4 hr, 20 mL (pH=5.4) natural dye was obtained from 20 g BWS as optimum value. In this study, leather coloration was performed bythe dyes produced fromGWS and BWS.The results indicated that leathers dyed with BWS performed better fastness properties when tested for light fastness,have higher color values and better dye penetration compared to those dyed with GWS.Overall, GWS and BWS dyes were not effective in dyeing leather considering rubbing, washing/laundering, water and perspiration fastness tests. However, they were different colorants. In conclusion, dyes produced from GWS and BWS are interesting and attractive due to tonal effects created by them. Luminous effect was observed in the dyed leathers. It is uncommon, preferred and economically valuable for leather industry. The main idea of this study is to introduce the chemical aspects, application methods and luminous properties of dyes produced from GWS and BWS for use

as a sustainable alternative in leather industry.This study would be a positive step to meet the need of leather industry in Turkey and a good example for cleaner production.

Acknowledgements

This research has been supported by Ömer Halisdemir University Scientific Research Projects Coordination Unit. Project Number: FEB 2016/04-BAGEP, 2016. Some part of this study was presented in 3rd International Conference on Engineering and Natural Science (Budapest, Hungary) and its abstract was published in Book of Abstract of this conference.The authors would like to thank Chemistry Department of Ömer Halisdemir University for laboratory conditions and instrumental analyses, Erzin Leather Industry and Trade Company (Nigde, Turkey) and Asım Erzin for applying the produced dye on the untreated leather samples, Eksoy Chemical Industry and Trade Inc. (Adana, Turkey), Celal Özgüven and Ayten Baş for performing colorfastness (light, rubbing, washing/laundering, water and perspiration fastness) tests.

References

[1] J-S. Hwang and S-Y. Park, "Application of green walnut husk of j*uglans regia* linn and effect of mordants for staining of silk," *Journal of Convergence Information Technology*, vol. 8, pp. 279-283, 2013.

[2] M. Carvalho, P. J. Ferreira, M. S. Mendes, R. Silva, J. A. Pereira, C. Jerónimo and B.M. Silva, "Human cancer cell antiproliferative and antioxidant activities of *Juglans regia L*.," *Food and Chemical Toxicology*, vol. 48, pp. 441-447, 2010

[3] V. K. Gupta and Suhas, "Application of low-cost adsorbents for dye removal-A review," *Journal of Environmental Management*, vol. 90, pp. 2313-2342, 2009.

[4] E. Forgacs, T. Cserháti and G. Oros, "Removal of synthetic dyes from wastewaters: a review," *Environment International*, vol. 30, pp. 953-971, 2004.

[5] H. S. Rai, M. S. Bhattacharyya, J. Singh, T. K. Bansal, P. Vats and U. C. Banerjee, "Removal of dyes from the effluent of textile and dyestuff manufacturing industry: a review of emerging techniques with reference to biological treatment", *Critical Reviews in Environmental Science and Technology*, vol. 35, pp. 219-238, 2005.

[6] Y. Yang, G. Wang, B. Wang, Z. Li, X. Jia, Q. Zhou and Y. Zhao, "Biosorption of acid black 172 and congo red from aqueous solution by nonviable Penicillium YW 01: Kinetic study, equilibrium isotherm and artificial neural network modelling," *Bioresource Technology*, vol. 102, pp. 828-834, 2011.

[7] H. B. Senturk, D. Ozdes and C. Duran, "Biosorption of Rhodamine 6G from aqueous solutions onto almond shell (Prunus dulcis) as a low cost biosorbent," *Desalination*, vol. 252, pp. 81-87, 2010.

[8] V. Vimonses, B. Jin and C. W. K, "Chow insight into removal kinetic and mechanisms of anionic dye by calcined clay materials and lime", *Journal of Hazardous Materials*, vol. 177, pp. 420-427, 2010.

[9] Y. N. Wang, H. X. Wang, Z. J. Shen, L. L. Zhao, S. R. Clarke, J. H. Sun, Y. Y. Du and G. L. Shi, "Methyl palmitate, an acaricidal compound occurring in green walnut husks," *Journal of Economic Entomology*, vol. 102, pp. 196-202, 2009.

[10] M.Mirjalili, K. Nazarpoor and L. Karimi, "Extraction and identification of dye from walnut green husks for silk dyeing," *Asian Journal of Chemistry*, vol. 23, pp. 1055-1059, 2011.

[11] G.W. Taylor, "Natural dyes in textile applications," *Review of Progress in Coloration*, vol. 16, pp. 53-62, 1986.

[12] ISO International Organization for Standardization, 2017, "ISO 15702. Leather-Tests for colour fastness-Colour fastness to machine washing", June 8, 2017. https://www.iso.org/standard/28714.html

[13] ISO International Organization for Standardization, 2017, "ISO 11642. Leather-Tests for colour fastness-Colour fastness to water", June 8, 2017. https://www.iso.org/standard/54446.html

[14] ISO International Organization for Standardization, 2017, "ISO 11641. Leather-Tests for colour fastness-Colour fastness to perspiration", June 8, 2017. https://www.iso.org/standard/54445.html

[15] ISO International Organization for Standardization, 2017, "ISO 105-B02. Textiles-Tests for colour fastness-Part B02: Colour fastness to artificial light: Xenon arc fading lamp test", June 5, 2017. https://www.iso.org/standard/65209.html

[16] ISO International Organization for Standardization, 2017, "ISO 11640. Leather-Tests for colour fastness- Colour fastness to cycles of to-and-fro rubbing", June 5, 2017. https://www.iso.org/standard/54444.html

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June2017, pp. 231~236
Available online at:*http://pen.ius.edu.ba*

Sustainability of Traditional Buildings Located in Rural Area

Pınar Usta[1], Ayşe Arıcı[2], Ahmet Evci[3], Engin Kepenek[4]
[1]Departement of Civil Engineering,Suleyman Demirel University
[2]Architecture Lecture,PhD program, Internacionalni University Travnik
[3]Departement of Civil Engineering, Afyon Kocatepe University
[4]Departement of Urban and Regional Planning, Suleyman Demirel University

Article Info

Article history:

Received June04th, 2017
Revised June15th, 2017
Accepted June17th, 2017

Keyword:

Traditional buildings
Rural area
Sustainability

ABSTRACT

In this days, sensitivity to environmental issues of people increased together with the awareness of the concept of sustainability. The structures, which are built in a rural residential area, are integrated with the natural environment. In Turkey, local traditional structures are structures that can be produced easily in place and materials are being used wisely. These houses which are used renewable natural materials carries a lot of features of the sustainable approach. Traditional structures have been shaped by the region where they are, because of the necessity. In this study, materials and construction systems of the traditional buildings which are located in rural areas are discussed and the buildings have been evaluated the context of ecology and sustainability.

Corresponding Author:

Pınar Usta,
Departement of Civil Engineering,
Suleyman Demirel University,
Suleyman Demirel University Road, Technology Faculty, Çünür 32200, Isparta, Turkey.
Email: pinarusta@sdu.edu.tr

1. Introduction

The rural settlements which have natural, historical, and traditional values have an important part of our cultural heritage. Nowadays, this settlements' traditional culture has begun to disappear for several reasons. This traditional texture has included some clever solutions about the usage of material and also sustainable design value. Constituting the majority of part of the historical texture in rural areas has many examples of civil architecture as mostly residential buildings [1].
Traditional buildings have better relations with the environment than the contemporary ones. Traditional buildings in Turkey inherit the values of various civilizations that have lived on these territories for centuries. Environmental factors have played an important role in design of these buildings, which rendered them more harmonized with the environment [2].
Turkish houses have features which unite them with antiseismic construction elsewhere. In almost every part of Turkey, there exist a large proportion of traditional buildings with ecological properties, energy and natural resources save-low environmental impact, which were built at various times in history [2].
Sustainability is a new concept with various perspectives in communities. Cities and rural areas are in the core of attention for developing.
There some elements which are needed to establish a sustainable economy in rural areas that are infrastructure, clean seeds, guidance in crops and livestock production, and credit as well as cooperatives, education, marketing facilities, farm machinery, water supplies, and diverse economic activities. All of them are necessary to establish a sustainable and efficient rural development in each village [3].
Sustainability, as a new paradigm in the past three decades, showed through some scientific evidence that flora and fauna species, water, air, forests, deserts and other ecosystems began to destroy and natural

resources were overused. Since sustainability is a multidimensional issue (local, regional, and international dimensions), it have to be developed at a level that people live, work and interact with each other and with nature such as local level [3].
The various sustainability issues are interwoven, and the interaction of a building with its surroundings is also important. The environmental issues share, in common, concerns which involve the reduction of the use of non-renewable materials and water, and the reduction of emissions, wastes, and pollutants [4].
Although social, economic, and cultural indicators are of significant importance to the concept of sustainable building, this concept is often based on environmental properties [4]. The concept of sustainability with respect to buildings is still poorly defined. Much of the focus is on the use of energy in buildings. Although sustainable building is a multidimensional concept, attention to the issue often focuses solely on environmental indicators, ignoring the substantial importance of social, economic and cultural indicators. Building sustainability involves various relations between built, natural and social systems [5].
Research in the area of sustainability has produced a significant amount of knowledge that is presented in the literature.
The aim of sustainability assessments is to gather and report information for decision-making during different phases of the construction, design, and use of a building.

2. Rural Area and Rural Structural Types in Turkey

Rural population (% of total population) in Turkey was last measured at 26.60 in 2015, according to the World Bank. Rural population refers to people living in rural areas as defined by national statistical offices. It is calculated as the difference between total population and urban population.This page has the latest values, historical data, forecasts, charts, statistics, an economic calendar and news for Rural population (% of total population) in Turkey [6]. Rural population is given Figure 1.

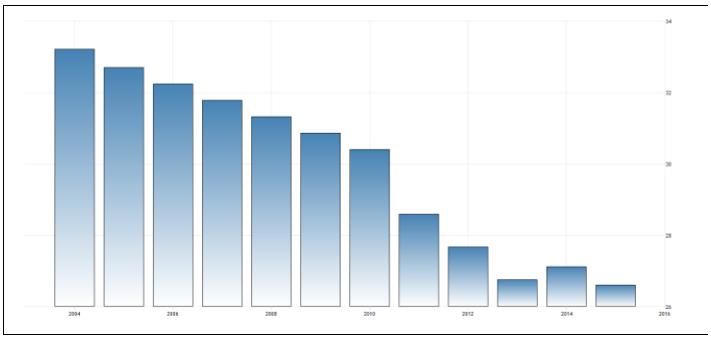


Figure 1. Rural Population of Turkey [6]

Buildings built in rural areas show significant differences depending on climatic conditions, preferred or locally available construction materials, traditions, income levels of the owners and their social habits. Rural housing types show themselves in different forms in different regions of our country. However, a particular type is most common in the area and it is said that this type of rural residence dominates the region [7]. In rural houses, whatever building materials stone, mud brick or wood, primitive construction technology is produced with materials and construction techniques close to each other all over the world [8].
Rural and urban settlements are the units that have different attributions and they do not have similar localities. These settlements have different lifestyles that have distinctive characteristics according to the economical and social activities and the relationship with the nature. Rural areas are qualified according to density of rural functions. These functions are showed up in using of land, in style of production style, in professional structure, in the characteristics of rural area and in the magnetic field of the producer and the service society. Because hegemony of the rural functions means less urban functions at the same time, 'rural areas' can be characterized as places that do not belong to urban areas [9].
The meaning of Rural Residence is the structures built by the dwellers themselves without any engineering services and with the use of local/regional material and technology. In addition to the rural areas many structures, which is located in around the metropolis, have been built without engineering services such as architectural design and static calculation. while building these structures people maintain to use constructional techniques, which are formed by instinctively rather than technically. The fact that the rural residences are still being constructed with the use of similar materials and construction technology all over the

world is a factor easing their classification. There are many types of structural systems traditional rural domestic architecture in Turkey, resulting from cultural attributes, related to material availability and climate. Modern buildings in the cities are generally built as reinforced concrete. Traditional wooden buildings were generally constructed in the ancient parts of city [10-11].
The rural residences are still being constructed with the use of similar materials and construction technology all over the world is a factor easing their classification [11].
There are different approaches to the classification of rural structures in Turkey. A classification based on the carrier characteristics of the building systems is given in Figure 2.2. and Distribution according to regions is given in Table 2.1. [12].

Table 1. Classification of standard buildings in Turkey [12] (Korkmaz, 2007)

Category	Type	Region	Description
wooden frame buildings	Rural "Himis"	North and West Anatolia	Frames made of unsorted and uncomplicated wood logs are filled with stone or mud brick. The dams are heavy, sometimes soil.
	Urban "Bagdadi"	West Anatolia	The thin horizontal slats are crushed and the wall padding is light and plastered to the wooden carrier frames that are carved and painted carefully.
Masonry Structure	Adobe	Central Anatolian	Walls made of mud, sometimes plastered with mud and heavy soil drips. Lintel and joinery are used from the tree logs.
	Stone	Eastern Anatolia	There are various types from mud mortar rubble to cement mortar stones. Sometimes only basements are made of stone.
	Blend Brick	All Region	It's a common building material. Lightweight, economic and also aesthetic constructions can be achieved.
	coring brick	All Region	It is used for making buildings such as bricks. The building is secured with lintel and lentiles.
	mixed	All Region	Concrete reinforced concrete structures on perforated brick walls and simple reinforced concrete columns with adobe filled walls
Reinforced concrete Structure		All Region	On-site pouring carcass buildings and fitted upholstery. Rarely prefabricated buildings are also found.

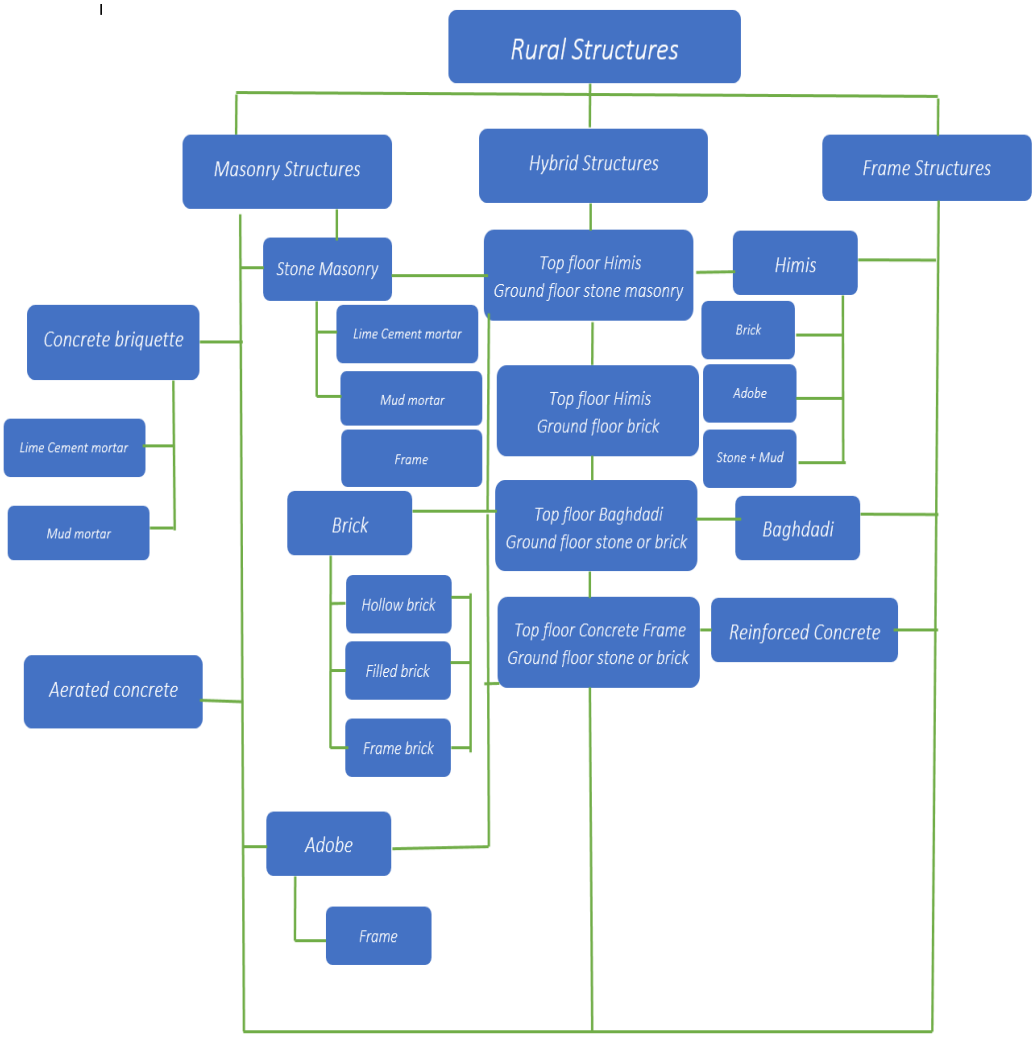


Figure 2. Classification of rural buildings in Turkey

3. Evaluation of Traditional Housing Architecture in the Context of Sustainability

In our country, where 35% of the population lives in rural areas, sustainable rural development is increasingly a challenge. In sustainable rural development with economic, social and environmental dimensions, one of the most important problems is the sustainability of the existing structures in the countryside and, together with this, the sustainability of local architecture and construction traditions in new constructions [13].

Local architecture is adaptable or exhibits features that can be improved over time as needs and conditions change. It is the basis for the sustainability of the interpretation of architectural designs in terms of the value of the local architects' own structure and the current technology. While local characteristics are being maintained, building a balance between the past and the future, depending on changing conditions, makes the architecture sustainable [14]. (Ovalı and Delibas, 2016).

The purpose of sustainable construction is "The creation and management of healthy environments based on the effective use of resources and ecological design". While traditional construction in rural settlements focuses on cost, performance and quality objectives, sustainable construction focuses on these goals in addition to minimizing resource consumption and environmental degradation and creating a healthy environment [13]. Sustainable structure can be summarized as a reflection of sustainability and sustainable development in the construction sector. Three sustainability indicators stand out in sustainable structures. These; Ecological sustainability, economic sustainability and social / cultural sustainability.

There exist several studies about rural structures and some of them given in Table 2. Table II summarizes scientific works available in the literature considering sustainability of the rural structures.

Table 2. Some works available in the literature about sustainability of rural structures

Authors	Year	Fields of application	Objectives of the evaluation
Tascı and Pekdogan [1]	2015	Sustainability, ecology, rural settlements,	To evaluated rural area and structures in terms of settlement of topography, relationship between green texture and housing, space organization also building materials and building forms variances
Altinkaya at all. [15]	2011	Sustainable housing, rural settlement	To evaluated Sustainability in Rural Settlements
Kusat [16]	2014	Rural development, Rural area, Sustainable development	To evaluated sustaınable rural development
Gorgulu and Koman [13]	2013	Rural housing, sustainable rural development, rural setlements, masonry construction.	To determine a masonry wall type for rural housing in the case of Kayseri
Sagıroglu and Karayazı [17]	2017	Rural Dwellings, Sustainability,	To Preservation of Traditional Rural Dwellings
Ovali and Delibas [14]	2016	Environmental sustainability, vernacular architecture	Analysis of rural area Within the Scope of the Sustainability of the Vernacular Architecture
Arpacioglu at all. [19]	2016	Rural Sustainability, Adobe, Traditional Construction, Energy Efficiency	To Conservation of Village Houses in the Context of Rural Sustainability

4. Conclusion

Preserving the local architectural heritage and transferring it to future generations is important in terms of sustainability. Local architecture must be studied and assimilated in order to determine the knowledge of production cultures based on experience and to convey the knowledge acquired in the production cultures created today.

Traditional settlements have been produced from existing sources, from readily available and transformable materials. They use the available resources to maintain thermal comfort without additional measures and thus carry sustainability principles. It is observed that traditional textures have a certain ecological sensitivity when their production and usage stages in the historical process are examined.

from a theoretical basis.

References

[1]. Tascı, B., Pekdogan, T. (2015). Examination of Traditional Dwelling Architecture in Rural Settlements in The Context of Sustainability : Kozbeyli. *2 nd International Sustainable Buildıngs Symposium,* 658-664.

[2]. Esin, T., & Yüksek, İ. (2008). A study on ecological properties of building materials used in traditional buildings (in Turkey). *Facilities*, *26*(5/6), 229-241.

[3]. Zolfani, S. H., & Zavadskas, E. K. (2013). Sustainable development of rural areas' building structures based on local climate. *Procedia Engineering*, *57*, 1295-1301.

[4]. Bragança, L., Mateus, R., & Koukkari, H. (2010). Building sustainability assessment. *Sustainability*, *2*(7).

[5]. Mateus, R., & Bragança, L. (2011). Sustainability assessment and rating of buildings: Developing the methodology SBTool PT–H. *Building and Environment*, *46*(10), 1962-1971.
[6]. http://www.tradingeconomics.com/turkey/rural-population-percent-of-total-population-wb-data.html
[7]. Bayülke N., 1984. Doğu Anadolu'daki Kırsal Konutların Deprem Davranışları Ve 30 Ekim 1983 Horasan Depreminde Gözlenmiş Hasar, Kuzeydoğu Anadolu I. Ulusal, Deprem Sempozyumu, Erzurum.
[8]. rıoğlu E.,Anadol K., 1974. Türkiye'de Kırsal Konutların Son Yıllardaki Tahripkar Depremlere Mukabelesi , Deprem Araştırma Bülteni, s:5, Ankara.
[9]. Gür, M., Cagdas, V., & Demir, H. (2003, December). Urban-Rural Interrelationship and Issues in Turkey. In *2nd FIG Conference, Marrakech, Morocco* (pp. 2-5).
[10]. Doğangün, A., Tuluk, Ö. İ., Livaoğlu, R., & Acar, R. (2006). Traditional wooden buildings and their damages during earthquakes in Turkey. *Engineering Failure Analysis*, *13*(6), 981-996.
[11]. Korkmaz, H. H., Korkmaz, S. Z., & Donduren, M. S. (2010). Earthquake hazard and damage on traditional rural structures in Turkey. *Natural Hazards and Earth System Sciences*, *10*(3), 605.
[12]. Korkmaz S.Z. (2007). Seismic improvement of rural houses, Selcuk University, Graduate school of natural sciences, Architecture Department, Phd Thesis, Konya.
[13]. Gorgulu, H.C., Koman, I. (2013). Kayseri Kırsalındaki Yığma Konutlar için Duvar Tipi Önerisi, *Tasarım+Kuram,* (15) 56-70.
[14]. Ovali, P. K., & Delibaş, N. (2016). Yerel Mimarinin Sürdürülebilirliği Kapsamında Kayaköy'ün Çözümlemesi.
[15]. Altinkaya, E.P., Tekin, C., & Eren. O. (2011)Sustainability in Rural Settlements: Adatepe and Demirciköy in Ayvacık Town in Çanakkale, *Journal of Polytechnic*, Vol: 14 No: 2 pp. 109-113.
[16]. Kusat. N. (2014). Rural Tourism as an Alternative For Sustainable Rural Development and Its Applicability in Turkey, *The International Journal of Economic and Social Research*, Vol. 10, Year 10, No. 2.
[17]. Sağiroğlu, Ö., & Karayazı, S. S. Akseki Belenalan Köyü Geleneksel Kirsal Konut Dokusunda Korumanin; Ekoturizm Yolu İle Sürdürülebilirliğinin Tespiti.
[18]. Arpacıoglu, U., Ozgunler, M. & Ozgunler S.E. (2016). Kırsal Sürdürülebilirlik Bağlamında Köy Evlerinin Korunması İçin Cephe ve Çatı Yaklaşımlarında Yeni Bir Model Köyünü Yaşat Projesi, 8. Ulusal Çatı & Cephe Sempozyumu 2– 3 Haziran 2016 Mimar Sinan Güzel SanatlarÜniversitesi Fındıklı-İstanbul

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 237~244
Available online at: http://pen.ius.edu.ba

Raman and FT-IRSpectra, DFT and SQMFF calculations forN,N-Dimethylaniline

Berna Çatıkkaş
Department of Physics, Mustafa Kemal University

Article Info

Article history:

Received May 30th, 2017
Revised June 15th, 2017
Accepted June 17th, 2017

Keyword:

Monoazo disperse dye
Infrared and Raman Spectroscopy
Scaled Quantum Mechanical Force Field (SQMFF)

ABSTRACT

Raman and FT-IR spectra of N,N-Dimethylaniline (DMA) molecule, which is a monoazo disperse dye, were recorded in the regions of 0 to 2085 cm^{-1}(Raman) and 350-4000 cm^{-1} (FT-IR).Vibrational frequencies calculation and molecular electronic potential surfacehave been computed by usingdensity functional B3LYP method with the 6-31+G(d,p) set for the ground state geometry of the title molecule.Total potential energy distributions (TED) was obtained with Scaled Quantum Mechanical calculationsto make thefundamental assignment.Assigned fundamental modes of DMA molecule were compared with the previous reported experimental values.

Corresponding Author:

Berna Çatıkkaş,
Department of Physics,
Mustafa Kemal University,
Tayfur Sökmen Campus, Antakya31034, Hatay, TURKEY.
Email: berna@mku.edu.tr

1. Introduction

For dying of natural and synthetic fibresare widelyused azo dyes[1], [2].For example, disperse dyes using has been continuouslyincreasing in the textile industry after the discoveryof synthetic fibres[1].Also,many high technology fields are using azo dyes, such as electronic devices, linear and nonlinear optics, reprography, sensors.Disperse dyes are the most important dyes group for dyeing of hydrophobic fibers[3]–[5].Molecular structure analysis of a monoazo disperse dye, N,N-dimethylaniline (DMA, as shown Fig. 1) molecule was fully characterized by Arslan et al.[6].

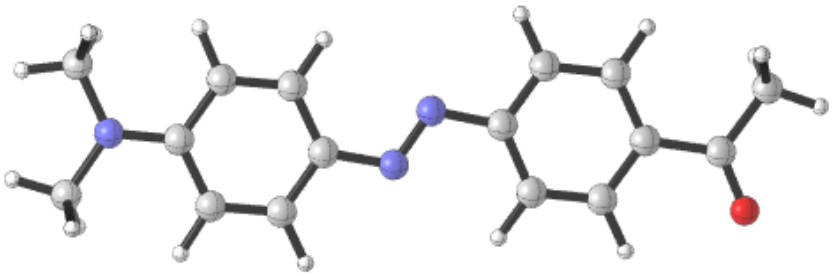


Figure 1. The optimized molecular structure of the DMA molecule (The structure were drawn using CYLview 1.0b[7]).

Calculated and experimental IR and Raman spectrums show that the all-inclusive picture on electronic possessions [8] and the correct structure information about thestudied molecule. Vibrational frequencies

investigation and detail IR and Raman spectroscopy analysis help for proper assignments of compound molecules. Then, the complete vibrational assignments and the simulated IR-Raman spectra of the fundamentals were constructed by using Density Functional Theory (DFT) and the scaled quantum mechanical force fields (SQMFF) procedure product of its potential energy distribution values.

2. Material and method

2.1. Experimental

The Infrared (IR) spectrum was recorded in the region 350-4000 cm^{-1} by using Perkin Elmer Spectrum Two with U-ATR FTIR spectrometer. In this study, the Raman spectrum was measured by using Renishaw inVia confocal Raman microscope (Gloucestershire, UK) and a nearinfrared diode laser (785 nm)maximum at 500mW, 1200 lines/mm source. A 1024×256 pixels CCD array detector detected Raman scattering signals. Raman range from 0 to 2085 cm^{-1} was detected with a 50× objective.

2.2. Computation

In this work, the calculations were carried outoptimized geometry, fundamental frequencies and amap of molecular electrostatic potential calculations by using DFT the B3LYP method and 6-31+G(d,p) basis set by utilizing the Gaussian 09 W[9] program package for studied molecule. The frequency calculations showed that the structure is in the state of the true minimum of potential energy.

The cartesian coordinates force fieldswere converted to the internal coordinates [10], [11] for the corresponding optimized structure. In the scaled quantum mechanical force fields[12]methodology, an internal coordinate representation of the cartesian force constants, which are obtained using B3LYP/6-31+G(d,p) level. Then the elements of the internal force constant matrix (F_{ij}(scaled)) are scaled based on scaled factors (s_i and s_j),

$$F_{ij}(\text{scaled})=(s_i)^{1/2}F_{ij}(s_j)^{1/2} \quad (1)$$

In this study, initial scaling factors (s_i) are used as recommendedby Baker[13], [14]in Table 1. Then direct scaling of the F=[F_{ij}] matrix is used for fitting the calculate fundamental wavenumbers to the corresponding experimental.

$$F_{ij}=(s_i s_j)^{1/2}F_{ij} \quad (2)$$

Table 1. Using initial scale factors (s_i)

Vibrations		Bonds	Scale factor
Stretching	1	C-N, N-N, C-O	0.9207
	2	C-H	0.9264
Bending	3	C-C-H	0.9431
	4	C-X-X	1.0144
Torsion	5	X-X-X-X	0.9523

Scaling factor optimization method is defined by merit function[14];

$$\chi^2(s_i) = \sum\{[v_i^{exp} - v_i^{theor}(s_i)]w_i\}^2 \quad (3)$$

In addition, thetotal energy distribution (TED)isdetermined stretching, bending or torsion percentages contribute to a particular normal mode. The Infrared and Raman spectrum were plotted in terms of Gaussian band shapes with 7 cm^{-1} bandwidth by using the SQM outputs. For scaling to getting these internal coordinate force were carried out with the scaledquantum mechanical force fields procedure by utilizing the Parallel Quantum Solutions (PQS) program [15].

Molecular electrostatic potential V(r)is definedbythe electronic density function: $\rho(r')$and Z_A is the charge on the nucleus A, located at R_A[16]–[18].

$$V(r) = \sum_A \frac{Z_A}{(R_A - r)} - \int \frac{\rho(r')}{(r' - r)} d(r') \quad (4)$$

To observe and get information about variably charged regions of the molecule, the map of molecular electrostatic potential was investigated using theoretical calculations.

3. Results and discussion

3.1. Vibrational assignments

The computed vibrational assignments were used for identifying the vibrational modes clearly in Fig.2., Fig.3. and Table 2. In this study, all weighted 105 fundamental frequencies RMS and mean average deviation are 7.46 and 3.78 respectively. The RMS values of the calculated SQM in the pre-fingerprint region (<500 cm^{-1}), fingerprint region (500-2500 cm^{-1}) and post-fingerprint region (>2500 cm^{-1}) are 3.45, 6.89 and 15.57, respectively. Hence, overall agreement between the SQM and experimental frequencies can be made with confidence. The both experimental and calculated IR and Raman spectrum of the title compounds are graphically illustrated in Fig. 2. and Fig. 3. The calculated SQMFF Raman and IR absorption spectrum bandwidth were plotted with 4 cm^{-1} in this study (in Fig. 2 and 3). The observed and calculated vibrational frequencies with the TED assignments were given in Table 2. Discussion for the characteristic spectral region is summarized as below.

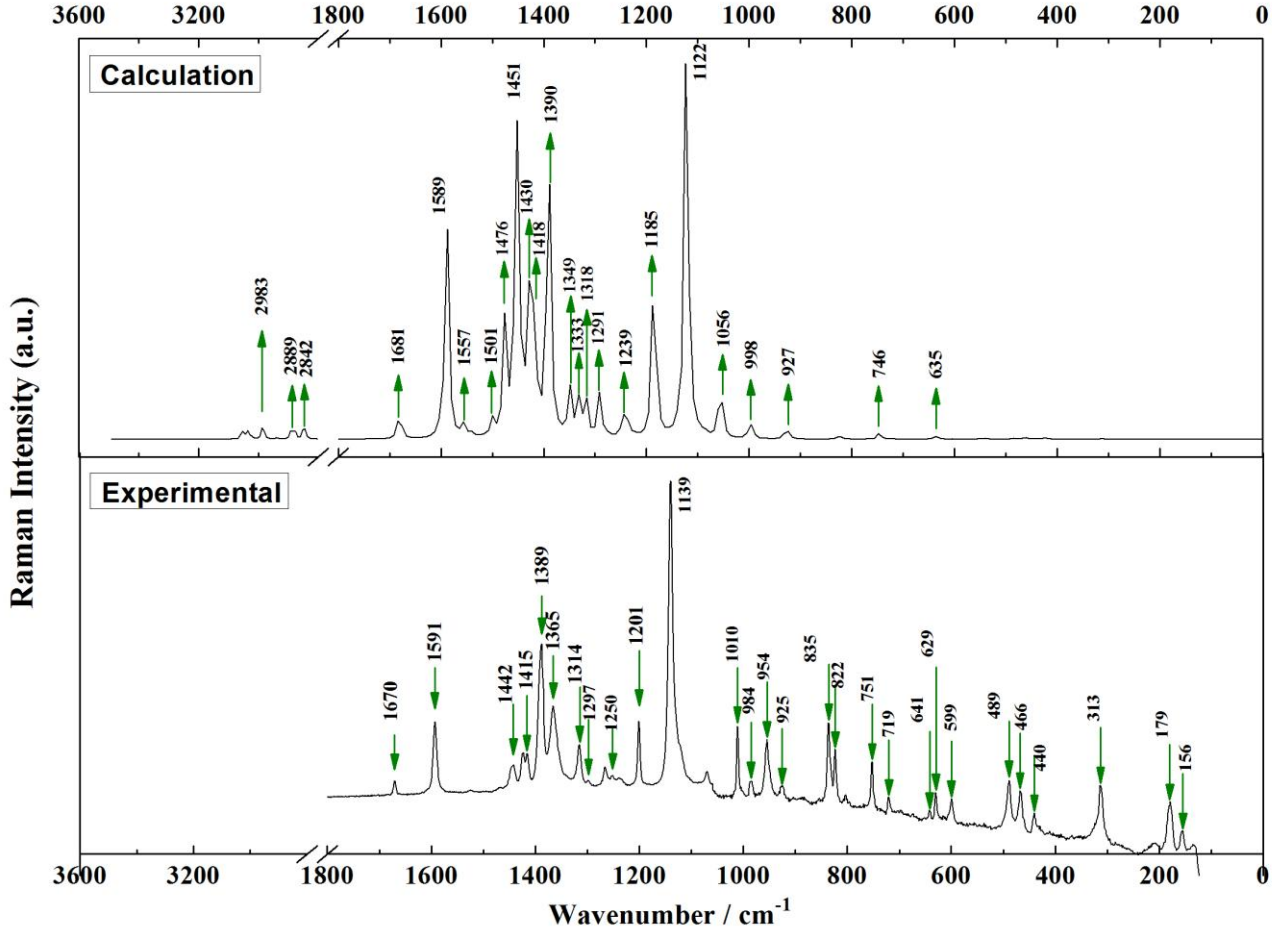


Figure 2. A comparison of the experimental (solid phase) Raman spectrum of DMA molecule with the calculatedRamanspectrum obtained at the B3LYP/6-31+G(d,p) level of theory within the SQMFF methodology.

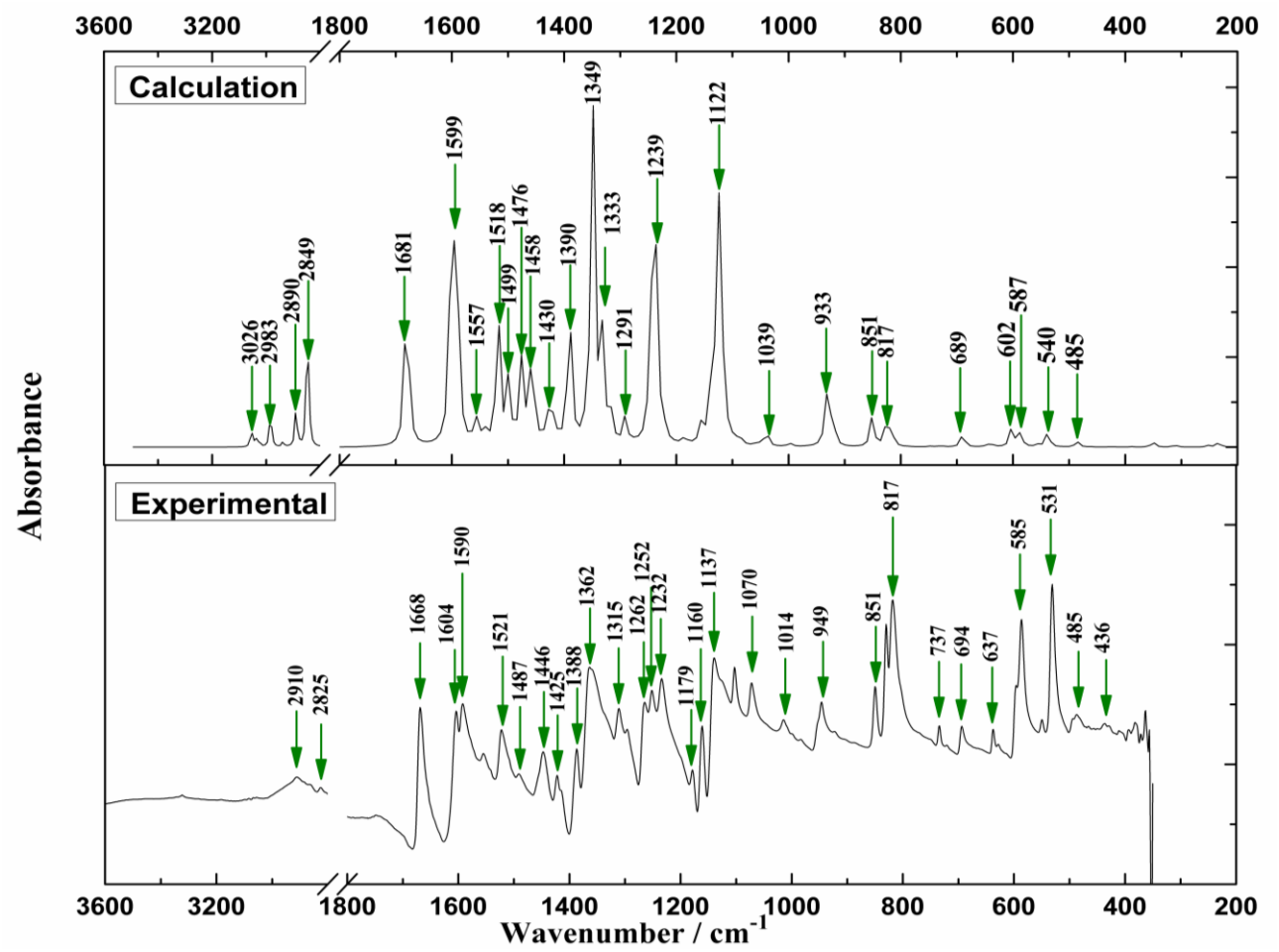


Figure 3. A comparison of the experimental (solid phase) IR spectrum of DMA molecule with the calculated IR spectrum obtained at the B3LYP/6-31+G(d,p) level of theory within the SQMFF methodology.

3.1.1. C-H vibrations

The aromatic C–H stretching vibrations are expected to appear wavenumber range 3100–3000 cm^{-1}[19]. Calculated SQM values of these bands at 3024 cm^{-1} to 3056 cm^{-1} are due to the C-H ring vibrations. C–H stretching vibrational modes in CH_3 groups are defined by the absorption bands in the 3000–2850 cm^{-1} range [19]. CH_3 symmetric stretching is assigned at 2910 cm^{-1}week band, while the calculated wavenumber is 2890 cm^{-1}.

3.1.2. N=N vibrations

Although azo compounds are no significant N=N stretching bands are expected in infrared spectroscopy, the N=N stretching band is generally strong intensity in Raman spectra[19]. Because of the azo compounds being non-polar in nature, the azo group is difficult to identify by infrared spectroscopy. In this study, N=N stretching vibrations are assigned 1368 cm^{-1} Raman and 1408 cm^{-1} and 1360 cm^{-1} IR[20]. The bands observed at 1488 cm^{-1} (IR), 1487 cm^{-1} (R), 1508 cm^{-1} (IR) and 1531 cm^{-1} (IR), 1532 cm^{-1} (R) in our before studies[21]. In this study, 1389 cm^{-1} strong Raman and 1425 cm^{-1} very weak IR band are observed, while the SQM 1418 cm^{-1}.

3.1.3. C-N vibrations

The characteristic functional of amine C-N range is expected 1240-1020 cm^{-1}[19]. The bands observed at very strong 1139 cm^{-1} and medium 1201 cm^{-1} Raman shift and also observed bands: 1179cm^{-1}, 1160cm^{-1}, 1137 cm^{-1} in the IR spectrum. The theoretically calculated CN vibrations (1122 cm^{-1}, IR and R, 1185 cm^{-1} medium IR and R) are in good agreement with the experimental bands.

Table 2. The assingments of the fundamental vibrations for the title molecule and comparison between the calculated DFT, SQM and observed experimental results

	B3LYP/ 6-31+G(d,p)			SQM			Observed[g]				
No	Freq[a]	I_{IR}[b]	I_{Raman}[c]	Freq[d]	I_{IR}[e]	I_{Raman}[f]	IR		Raman		TED(Total Energy Divibution)(>5%)[h]
105	3233	18.4	162.8	3056	18.3	162.3					CH sym v(95)
104	3230	12.3	52.2	3054	12.4	47.7					CH sym v(91)
103	3230	0.2	75.0	3053	0.1	79.9					CH sym v(95)
102	3216	3.2	54.6	3040	3.2	55.2					CH asym v(99)
101	3214	11.8	150.6	3039	11.8	150.2					CH sym v(98)
100	3211	1.2	75.5	3035	1.2	76.0					CH asym v(98)
99	3201	2.8	59.8	3026	2.8	59.7					CH asym v(99)
98	3199	6.1	57.6	3024	6.2	58.0					CH asym v(99)
97	3161	17.5	199.1	2988	17.4	199.2					CH3 asym v(100)
96	3156	43.5	270.2	2983	43.6	270.0					CH3 asym v(94)
95	3143	1.6	7.2	2971	1.6	7.3					CH3 asym v(93)
94	3108	8.4	51.0	2938	8.4	51.1					CH3 asym v(100)
93	3057	72.6	145.6	2890	72.7	145.7	2910	w			CH3 sym v(99)
92	3056	0.0	165.5	2889	0.0	165.0					CH3 asym v(100)
91	3045	3.5	252.3	2879	3.5	251.8					CH3 sym v(100)
90	3014	152.4	318.4	2849	151.3	319.1					CH3 sym v(94)
89	3007	91.7	192.8	2842	91.6	192.6	2825	vw			CH3 asym v(93)
88	1744	295.0	632.9	1681	286.1	617.4	1668	m	1670	w	CO v(83)
87	1658	518.5	316.9	1599	513.9	272.6	1604	m			CC v(55)
86	1647	138.5	4089.2	1589	162.7	4278.9	1590	m	1591	m	CC v(53) + NN v(5)
85	1610	24.9	106.7	1557	41.2	276.0					CC v(63)
84	1593	27.2	94.7	1543	26.5	107.0					CC v(60)
83	1559	354.4	73.4	1518	219.5	6.9	1521	m			CH3 b(50) + HCN b(17) + CN v(6)
82	1538	2.0	1271.2	1501	36.7	241.9					CH3 b(35)
81	1532	118.5	727.6	1499	72.4	92.3	1487	vw			HCH b(22)+NC v(9) +NN v(5)
80	1523	0.8	95.4	1478	14.8	36.0					HCH b(44)+HCNC t(21)
79	1501	185.9	1100.6	1476	119.1	2155.0					HCC b(18)+ NN v(15) + CC ring v(13)
78	1497	15.0	35.9	1469	0.0	7.2					CH3 b(58)
77	1493	18.8	215.5	1467	11.9	13.1					CH3 b(60)
76	1488	0.0	7.2	1458	134.1	1257.4					CH3 b(34)
75	1486	11.7	13.3	1456	13.9	75.2					CH3 b(63) + t(31)
74	1476	6.4	325.5	1451	14.4	6060.0	1446	vw	1442	w	NN v(15) + CC ring v(8)
73	1475	115.3	3765.5	1430	50.7	2769.4			1415	w	NN v(10) + CC ring v(7) + CH3 b(35)
72	1452	3.4	181.6	1418	46.7	2371.7	1425	vw	1389	s	NN v(8) + CC ring v(19) + t(35)
71	1440	171.8	4393.3	1390	239.6	6536.5	1388	vw			CC ring v(21) + HCC ip b(20) + NN v(16)
70	1396	503.6	828.6	1359	30.9	37.8	1362	m	1365	m	CH3 b(89)
69	1391	118.9	42.3	1349	549.6	907.7					CN v(37) + CC ring v(6)
68	1378	137.6	496.6	1333	169.7	673.8					CC ring v(62)
67	1365	36.8	725.8	1318	55.5	868.9	1315	w	1314	m	CC ring v(74)
66	1341	42.5	681.0	1291	42.9	882.9	1310	vw	1297	vw	HCC ring b(70)
65	1326	0.1	73.3	1274	2.2	60.6	1262	m			HCC ring b(73)
64	1293	10.9	204.6	1246	68.4	324.9	1252	m	1250	vw	CN v(24) + CC v(14)
63	1280	538.7	705.7	1239	517.7	423.4	1232	m	1240	vw	CN v(24) + CC v(26)
62	1274	77.4	159.0	1224	39.3	89.0					CN v(39) + CC v(22) + HCC(7) + HCN(5)
61	1229	1.8	2467.0	1185	11.7	3657.5	1179	w	1201	m	CN v(25) + CC v(14) + HCC ip b(6)
60	1198	46.3	14.8	1155	30.2	21.2	1160	w			HCN b(33) + CN v(8)
59	1185	133.6	73.3	1136	168.5	186.4	1137	m	1139	vs	CN v(8) + HCC ip b(34)
58	1165	510.4	25.9	1122	480.5	8284.2					CN v(17) + HCC ip b(27)
57	1148	15.7	311.8	1105	10.9	136.5					HCC ip b(58) + CC v(18)
56	1141	0.0	0.9	1096	0.0	1.0					HCN b(78)
55	1138	0.1	0.3	1092	0.2	0.5					HCN b(80)
54	1132	15.7	245.4	1088	12.4	100.2					CC ring v(22) + HCC ip b(58)
53	1089	3.1	608.9	1056	5.4	1099.5	1070	m			CC ring v(25) + CC v(10) + OCC b(7)+ CCC b(16)

Table 2.(Continued)

	B3LYP/ 6-31+G(d,p)			SQM			Observed[g]			
No	Freq[a]	I_{IR}[b]	I_{Raman}[c]	Freq[d]	I_{IR}[e]	I_{Raman}[f]	IR	Raman		TED(Total Energy Divibution)(>5%)[h]
52	1082	26.3	5.0	1039	26.2	5.1				HCN b(36) + CN v(29)
51	1044	0.6	0.4	1008	0.3	0.7	1014 vw	1010	m	HCC b(43) + t(37)
50	1022	2.7	251.5	998	5.1	297.7				HCC ring ip b(66) + CC(31)
49	1013	0.2	15.1	994	0.4	0.1				t(67) + HCC b(11)
48	1010	0.2	0.3	989	0.2	38.2		984	w	CCC ring op b(75) + CC ring v(21)
47	982	0.4	0.3	967	0.3	0.3				t(78)
46	977	0.2	0.8	962	0.1	0.7				t(81)
45	967	1.6	0.1	952	1.3	0.1		954	m	t(78)
44	964	38.0	7.6	933	69.2	27.0	949 m			CN v(32) + CNN b(14)
43	960	98.9	150.4	927	44.2	179.5		925	w	CC v(25) + HCC b(27)
42	937	0.5	20.2	919	24.1	19.5				CC v(28) + CNN b(24)
41	873	48.1	0.4	851	49.4	0.4	851 m			t ring op(76)
40	850	6.1	77.1	828	23.4	0.4		835	m	t ring breath(75)
39	849	20.5	0.4	824	6.5	66.7		822	m	CC v(36) + CN v(19) + CCC ring ip b(5)
38	837	37.8	0.0	817	33.6	0.0	817 vs			t ring op(62)
37	810	0.6	0.9	790	0.5	0.8				t ring op (93)
36	761	0.3	79.6	746	1.6	114.1		751		CN v(13) + CC v(11) + CCC ip ring(6)
35	745	2.0	0.5	728	2.1	0.3	737 w	719		t(6)
34	732	0.1	3.9	715	0.0	4.2				t(7)
33	707	23.6	1.8	689	22.9	1.2	694 w			CCC ring b ip(27) + CN b(27) + CC v(20)
32	653	4.1	2.5	646	4.4	2.7		641		CCC ring b ip(27)
31	642	2.3	43.2	635	2.8	48.4	637 w	629		CCC ring b ip (35)
30	608	36.1	2.3	602	34.5	3.1		599		CC v(18) + OCC b(33)
29	603	21.7	0.4	587	22.7	0.4	585 s			HCC b(13) + t(34)
28	559	4.2	1.8	557	3.7	3.3				NNC b(11) + CNC b(9) + NCC b(7) + OCC b(6)
27	548	13.5	1.9	540	12.1	14.4				NCC b(16) + CNC b(12) + NNC b(8) + OCC b(5)
26	541	12.3	14.8	537	12.7	1.8	531 s			t(37)
25	502	0.9	0.1	490	0.9	0.1		489		t inter ring(11)
24	488	9.4	15.1	485	7.9	12.9	485 w			CNC b(26) + CCC b(15) + OCC b(6) + NCC b(5)
23	466	0.5	36.3	462	0.4	35.0		466	w	CNC b(29) + NCC b(6) + NNC b(5) + OCC b(5)
22	446	0.0	0.3	435	0.0	0.3	436 vw	440	vw	tros(70)
21	426	0.9	23.8	424	0.9	30.0				CCC b(19) + CNC b(17) + OCC b(10) + NC v(6)
20	420	0.0	0.0	409	0.0	0.0				t(77)
19	396	0.5	0.7	387	0.5	0.7				t(43)
18	354	9.0	0.7	350	8.6	1.0				CC v(15) + CN v(6) + CCC b(12) + OCC b(11) + CNC b(8)
17	315	1.3	3.0	313	1.9	3.5		313	m	NCC b(43) + CNC b(20)
16	313	2.0	3.4	308	1.4	3.0				t(38)
15	257	2.5	0.3	251	2.5	0.4				CH3 t(60)
14	232	7.7	1.0	233	7.9	1.1				NCC b(28) + CCC b(26) + CNC b(19)
13	204	0.1	0.2	199	0.1	0.2				CH3 t(72)
12	188	6.1	1.4	186	6.5	1.9		179	w	CN v(14) + CNN b(6) + CCC b(26)
11	171	0.9	1.9	167	0.9	1.9				t(51)
10	162	0.1	0.2	157	0.1	0.2		156	vw	t(100)
9	147	0.8	1.7	147	0.6	2.0				NCC b(30) + NNC b(6) + CCC b(16)
8	143	0.5	0.9	140	0.5	0.8				t(45)
7	74	0.2	1.4	72	0.1	1.4				t(52)
6	69	1.4	0.3	68	1.6	0.3				t(40)
5	62	2.8	1.0	60	2.8	1.0				t(73)
4	48	0.5	0.9	49	0.5	0.9				CNN b(90)
3	41	0.8	1.9	40	0.8	1.9				t(63)
2	25	2.5	1.2	24	2.4	1.2				t(61)
1	18	0.1	0.3	18	0.1	0.3				t(80)

[a] Harmonic Vibrational Frequencies; [b] Infrared Intensities; [c] Raman Intensities;

[d]SQM Frequencies; [e]Infrared Intensities; [f]Raman Intensities; [g] vw, very weak; w, weak; m, medium; s,vong; vs, very vong

[h]The number after the modes are the % potential energy calculated using normal coordinate analysis; v, stretching; b, bending; t, torsion

3.2. Molecular electrostatic potential

The map of molecular electrostatic potential (MEP) surface visualizes the reactive sites of the DMA (in Fig. 4).The electrostatic potential increases red toblue potential region (red<orange<yellow<green<cyan<blue)positive and negative respectively. Map of electrostatic potential contour positive and negative potentials for the DMA compoundare figured out in Fig. 5, at B3LYP/6-31+G(d,p) level.

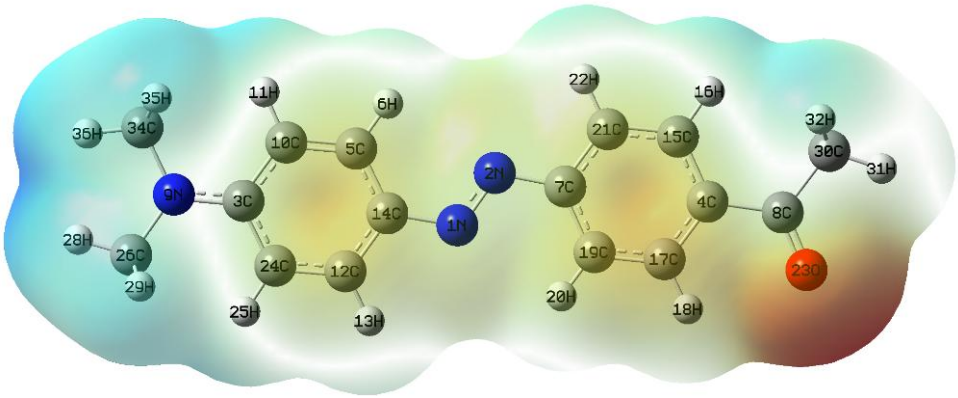


Figure 4. The 3D map of MEP surface of the DMA molecule.

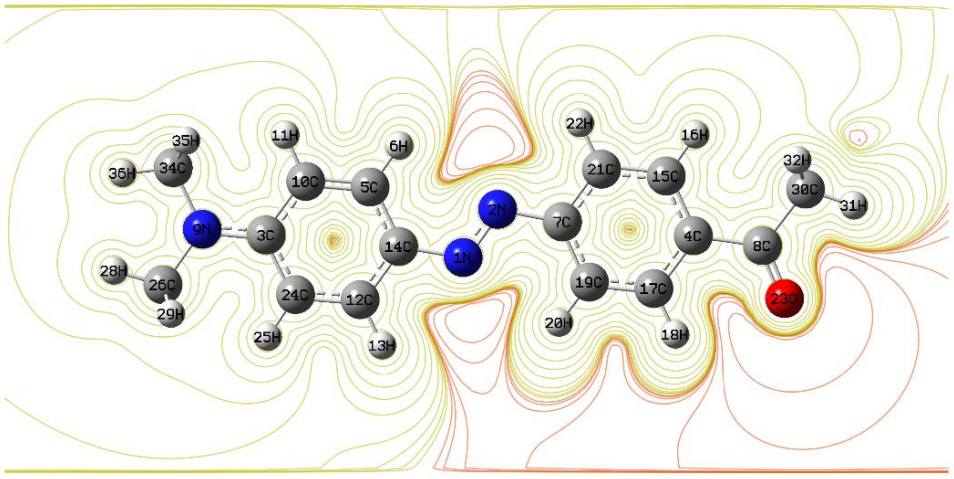


Figure 5. The 2D map of MEPcontourof the DMA molecule.

4. Conclusions

The experimental and theoretical values of the vibrational frequencies of the studied molecule were compared. The RMS and mean average deviation of DMAfundamental vibrations were found as 7.46 and 3.78, respectively. This shows that the calcaulated frequencies are in good agreement with the experimental ones.

Acknowledgements

This study was supported by the Research Foundation of Mustafa Kemal University Project No: 15109. The author thankstoZeynel Seferoğlu for his support giving permission to use the material, N,N-dimethylaniline. I would like to thank the Gazi University for providing Gaussian 09W Software. The numerical calculations reported in this paper were performed at TUBITAK ULAKBIM, High Performance and Grid Computing Center (TRUBA Resources).

References

[1] M. Neamtu, A. Yediler, I. Siminiceanu, M. Macoveanu, and A. Kettrup, “Decolorization of disperse red 354 azo dye in water by several oxidation processes - a comparative study,” *Dye. Pigment.*, vol. 60, no. 1, pp. 61–68, 2004.

[2] A. G. Tskhovrebov, L. C. E. Naested, E. Solari, R. Scopelliti, and K. Severin, "Synthesis of azoimidazolium dyes with nitrous oxide," *Angew. Chemie - Int. Ed.*, vol. 54, no. 4, 2015.
[3] H. Valizadeh and A. Shomali, "A new nitrite ionic liquid (IL-ONO) as a nitrosonium source for the efficient diazotization of aniline derivatives and in-situ synthesis of azo dyes," *Dye. Pigment.*, vol. 92, no. 3, pp. 1138–1143, 2012.
[4] A. Matei, C. Constantinescu, B. Mitu, M. Filipescu, V. Ion, I. Ionita, S. Brajnicov, A. P. Alloncle, P. Delaporte, A. Emandi, and M. Dinescu, "Laser printing of azo-derivative thin films for non-linear optical applications," *Appl. Surf. Sci.*, vol. 336, pp. 200–205, 2015.
[5] S. Shahab, F. H. Hajikolaee, L. Filippovich, M. Darroudi, V. A. Loiko, R. Kumar, and M. Y. Borzehandani, "Molecular structure and UV–Vis spectral analysis of new synthesized azo dyes for application in polarizing films," *Dye. Pigment.*, vol. 129, pp. 9–17, 2016.
[6] Ö. Arslan, E. Yalçin, N. Seferoğlu, M. Yaman, and Z. Seferoğlu, "Molecular Structure Analysis and Spectroscopic Properties of Monoazo Disperse Dye From N , N -Dimethylaniline," vol. 30, no. 1, pp. 175–189, 2017.
[7] C. Y. Legault, "CYLview, 1.0b," *Univ. Sherbrooke*, p. http://www.cylview.org, 2009.
[8] M. Suhasini, E. Sailatha, S. Gunasekaran, and G. R. Ramkumaar, "Vibrational and electronic investigations, thermodynamic parameters, HOMO and LUMO analysis on Lornoxicam by density functional theory," *J. Mol. Struct.*, vol. 1100, pp. 116–128, Nov. 2015.
[9] M. J. et al Frisch, "Gaussian 09, Revision A.02," *Gaussian 09, Revision A.02*. 2009.
[10] G. Fogarasi, X. Zhou, P. W. Taylor, and P. Pulay, "The calculation of ab initio molecular geometries: efficient optimization by natural internal coordinates and empirical correction by offset forces," *J. Am. Chem. Soc.*, vol. 114, no. 21, pp. 8191–8201, 1992.
[11] P. Pulay, G. Fogarasi, G. Pongor, J. E. Boggs, and A. Vargha, "Combination of theoretical ab initio and experimental information to obtain reliable harmonic force constants. Scaled quantum mechanical (QM) force fields for glyoxal, acrolein, butadiene, formaldehyde, and ethylene," *J. Am. Chem. Soc.*, vol. 105, no. 24, pp. 7037–7047, 1983.
[12] P. Pulay, G. Fogarasi, F. Pang, and J. E. Boggs, "Systematic ab Initio Gradient Calculation of Molecular Geometries, Force Constants, and Dipole Moment Derivatives," *J. Am. Chem. Soc.*, vol. 101, no. 10, pp. 2550–2560, 1979.
[13] P. Pulay, G. Fogarasi, G. Pongor, J. E. Boggs, and A. Varghale, "Combination of Theoretical ab Initio and Experimental Information To Obtain Reliable Harmonic Force Constants . Scaled Quantum Mechanical (SQM) Force Fields for," *J. Am. Chem. Soc.*, vol. 105, no. Figure 3, pp. 7037–7047, 1983.
[14] J. Baker, A. A. Jarzecki, and P. Pulay, "Direct Scaling of Primitive Valence Force Constants: An Alternative Approach to Scaled Quantum Mechanical Force Fields," *J. Phys. Chem. A*, vol. 102, no. 8, pp. 1412–1424, 1998.
[15] "Parallel Quantum Solutions, SQM." Green Acres Road, Suite A, Fayetteville, AR 72703, 2013.
[16] P. Politzer, P. R. Laurence, and K. Jayasuriya, "Molecular electrostatic potentials: An effective tool for the elucidation of biochemical phenomena," *Environ. Health Perspect.*, vol. VOL. 61, no. 1, pp. 191–202, 1985.
[17] P. Politzer and J. S. Murray, "The fundamental nature and role of the electrostatic potential in atoms and molecules," *Theor. Chem. Acc.*, vol. 108, pp. 134–142, 2002.
[18] G. L. Hofacker, "Peter Politzer und Donald G. Truhlar: Chemical Applications of Atomic and Molecular Electrostatic Potentials, Plenum Press, New York und London 1981. 472 Seiten, Preis: $ 55.-," *Berichte der Bunsengesellschaft für Phys. Chemie*, vol. 86, no. 9, pp. 872–873, Sep. 1982.
[19] G. Socrates, *Infrared and Raman characteristic group frequencies*. 2004.
[20] B. Çatıkkaş, E. Aktan, and Z. Seferoğlu, "DFT, FT-Raman, FTIR, NMR, and UV-Vis studies of a hetarylazo indole dye," *Int. J. Quantum Chem.*, vol. 113, no. 5, pp. 683–689, Mar. 2013.
[21] E. Aktan, B. Babür, Z. Seferoğlu, T. Hökelek, and E. Şahin, "Synthesis and structure of a novel hetarylazoindole dye studied by X-ray diffraction, FT-IR, FT-Raman, UV–vis, NMR spectra and DFT calculations," *J. Mol. Struct.*, vol. 1002, no. 1–3, pp. 113–120, Sep. 2011.