ETHIOPIAN INTERNATIONAL JOURNAL OF ENGINEERING AND TECHNOLOGY

"exploration of novel knowledge"

ISSN (E): 2959-3921,
ISSN (P): 2959-393X (PROVISIONAL)

www.amu.edu.et
eijet@amu.edu.et

Volume - I
ISSUE - 1
April - 2023

ETHIOPIAN INTERNATIONAL JOURNAL OF ENGINEERING AND TECHNOLOGY (EIJET)

ISSN (E): 2959-3921, ISSN (P): 2959-393X (PROVISIONAL)

VOLUME-1 (2023), ISSUE-I

APRIL, 2023

ARBA MINCH, ETHIOPIA

Journal: Vol. 1 (2023), Issue 1

Published by Arba Minch University

About EIJET

The **Ethiopian International Journal of Engineering and Technology (EIJET)** is a non-profit peer-reviewed open-access academic research Journal of Arba Minch Institute of Technology under Arba Minch University, Ethiopia. The scope of the Journal covers multidisciplinary and cross-disciplinary areas of study in engineering and technology. The peer-reviewed International Journal publishes all types of quality research papers, case studies, review papers, experimental and empirical papers, and shortened thesis/ dissertations in the broad area of engineering and technology.

The Journal is specifically dedicated to publish novel research contributions and innovative research outcomes in the following fields of engineering and technology: -

- Intelligent Computing and Information Technology,
- Mechanical and Metallurgy Engineering,
- Architectural Design and Town Planning,
- Civil and Transport Engineering Systems,
- Electrical Engineering and Power Electronics,
- Emerging areas of Renewable Energy
- Papers related to allied disciplines, emerging technologies, and future-generation engineering will be given priority for publication.

The Journal publishes papers from worldwide sources, especially for covering the emerging issues of engineering and technology from developing and developed countries. The Papers from African continent countries having localized problem-solving research will be given priority.

Table of Contents

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC6

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

APPLICATIONS OF MULTIMODAL BIOMETRICS AUTHENTICATION FOR ENHANCING THE IOT SECURITY USING DEEP LEARNING

Gergito Kusse[1*] and Tewoderos Demissie[2]

[1] *Lecturer, Department of Computer Science, Debre Tabor University, Ethiopia,*

[2]*Lecturer, Department of Information Technology, Bule Hora University, Ethiopia,*

Corresponding author: *gergito2@gmail.com*

Abstract

The Internet of Things (IoT) integrates billions of electronic devices into computer networks to provide advanced and intelligent services that enable devices to communicate with each other by exchanging information with minimal human interaction. The security issue is at higher risk in IoT systems than in other computing systems. Maintaining the security requirement when attacking the physical surface of the IoT system device is a challenging task. Implementing security mechanisms like authentication and access control for the IoT ecosystem is necessarily needed to ensure the security of IoT devices. The key used for security may be stolen, forgotten, or forged. Also, the key may be generated by intruders or men in the middle of traditional security mechanisms. Biometric security is becoming more advanced and sophisticated with technological advancements and is mostly used in authentication systems. In unimodal biometrics, only one biometrics character can be applied which does not apply to ensure the security of IoT systems. In this paper, Multimodal biometrics authentication was used for securing edge devices in the IoT ecosystems. Face image and fingerprint image were used as multimodal biometrics systems for authenticating users to secured IoT devices. A pi-camera module and fingerprint sensor were used to capture biometric data. Image processing techniques were then applied to the images. Then CNN algorithms were used for feature extraction and model creation. During model creation, the RELU function was used as an activation function, soft-max for image classification, and Max-pooling for image dimensional reduction which helped the model speed up the training process. Experimental results show that the accuracy of the face image and fingerprint image is 92% and 89% respectively, which is a promising result that achieves the objective of the study.

Keywords: ***Internet of Things, Multimodal Biometrics, Authentication, CNN, Deep Learning***

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*

Corresponding author- ***Gergito Kusse***

I. Introduction

IoT integrates billions of electronic devices into networks to provide advanced and intelligent services that can communicate with one another by exchanging information with minimal human intervention. IoT structures are complicated and contain integrative arrangements. Therefore, maintaining the security requirement in attacking the physical surface of the IoT system device is challenging. The security issue is at higher risk in IoT systems than in other computing systems, and the traditional solution may be ineffective for such systems. Solutions have to include holistic considerations to meet the safety requirement. However, IoT devices are usually paintings in unattended surroundings. Consequently, an interloper may additionally bodily get admission to those gadgets. IoT gadgets are related normally over Wi-Fi networks in which an outsider might also access private facts from a communication channel with the aid of eavesdropping. IoT devices cannot support complex security structures given their limited computation and power resources [1].

Biometric authentication is a security process that relies on the unique biological characteristics of individuals to verify who they are [2]. Biometric authentication and recognition have become the new branch of exploration in the adoption of newer techniques in terms of security, higher accuracy, and high speed [3]. Unimodal biometric authentication structures got more interest from sensible programs [4] consisting of the Internet of Things (IoT), Automated Teller Machines (ATM), and cellular packages. Thus, one feature is commonly neither green nor enough to expect the proper subject, particularly for the accrued photos in diverse conditions such as illumination, rotation, and occlusion conditions. Therefore, most researchers pay more attention to multimodal biometric recognition to grow identity performance and provide greater protection. Most of the latest human-popularity works [5] utilized function-degree fusion to overcome the challenges of confined assets and to boom device security and device overall performance.

Artificial intelligence is the way of creating an intelligent system that thinks and acts like a human being. It is a way of using computer machines as a power of humans [6]. A system to be an intelligent system should have six disciplines of AI (NLP, computer vision, machine learning, knowledge representation, robotics, and logical reasoning). In the current era, AI is used in

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Gergito Kusse***

different areas like healthy cars, agriculture, education, and industry. In industry IoT and AI systems are commonly used to improve services and produce more products for customers.

In the IoT ecosystem, complex structures and heterogeneous components are interconnected. In the current era of globalization, most of the systems in industrial companies are migrating to IoT technology. Edge devices in IoT can exchange data with less human interaction. Ensuring security for the IoT ecosystem is necessarily needed to avoid unauthorized access to IoT systems.

Researchers did different security mechanisms to ensure security in IoT systems. In the last decades, traditional security mechanisms were applied to secure edge devices in an IoT ecosystem. Traditional security mechanism has a drawback because the key used for the security method may get stolen, forgotten, or forged key may be created by intruders or a man in the middle, but in biometric security mechanism the character or the key can't be stolen by theft, forgotten, and fake character cannot be generated by the intruders. The biometric character may be physiological (face, fingerprint, iris, hand geometry, hand gesture) or behavioral (walking, typing, touchpad). Most researchers applied either of these biometrics to improve security issues in IoT.

Researchers were applying biometrics in two ways. The first one is a unimodal biometrics system. In unimodal biometrics, only one biometrics character was applied which does not apply to ensuring security in IoT systems. The second one is multimodal biometrics systems that can apply more than one biometrics characteristic.

II. Literature Review

Research by Mohammed Ali Al-Garadi, Amr Mohamed, and Abdulla Al-Ali [7] proposed a review of the machine learning and deep learning methods and algorithms applied to the Internet of Things IoT security which is titled "Survey of security issues Machine and deep learning knowledge of techniques for Internet of Things". In this paper, the researchers tried to address all the methods and algorithms of machine learning and deep learning and how they are applied for ensuring the security of IoT.

Another study by Jasmeen Sharma, and Dharam Veer Sharma [8] proposed a multimodal biometrics authentication using face and fingerprint. They tried to address the drawback of unimodal biometrics and how the multimodal biometric system was very advanced than the

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Gergito Kusse***

unimodal biometrics. The researchers used principal component analysis (PCA), Bacterial Foraging Optimization algorithms (BFOA), Minute Extraction, and multilayer (MLNN).

In another paper, Sudip Vhaduri and Christian Poellabauer [9] proposed "Multimodal biometric-based implicit authentication of wearable devices users". They applied authentication mechanisms using combinations of three types of coarse-grain minute-level biometrics: behavioral (step counts), physiological (heart rate), and hybrid (calorie burn and metabolic equivalent of task). Their findings show that hybrid biometrics perform better than other biometrics and behavioral biometrics do not have a significant impact, even during non-sedentary periods.

Very important research by Mohamed Hammad, Yashu Liu, And Kuanquan Wang [10] proposed a "Multimodal biometric authentication system using CNN based on a different level fusion of ECG and fingerprint". They developed two authentication systems with two different level fusion algorithms: feature-level fusion and decision-level fusion. The feature extraction for users' modalities is done through the usage of CNN.

III. Research Design and Methodology

A comprehensive overview of multimodal biometric authentication for enhancing IoT security systems with face recognition and fingerprint biometric data was discussed. For the experimental investigation, images were collected through the pi-camera and fingerprint sensor.

A. Proposed Model Architecture

The proposed model contains two phases, the enrollment phase, and the authentication phase. Both phases have the same image-processing tasks. First digital face image and fingerprint images are acquired by using the Pi camera module and fingerprint sensor devices respectively. Then the image preprocessing technique is applied. The segmentation process was applied to the image which is then ready for the feature extraction process. The following Fig.1 shows the proposed model architecture.

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Gergito Kusse***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC6

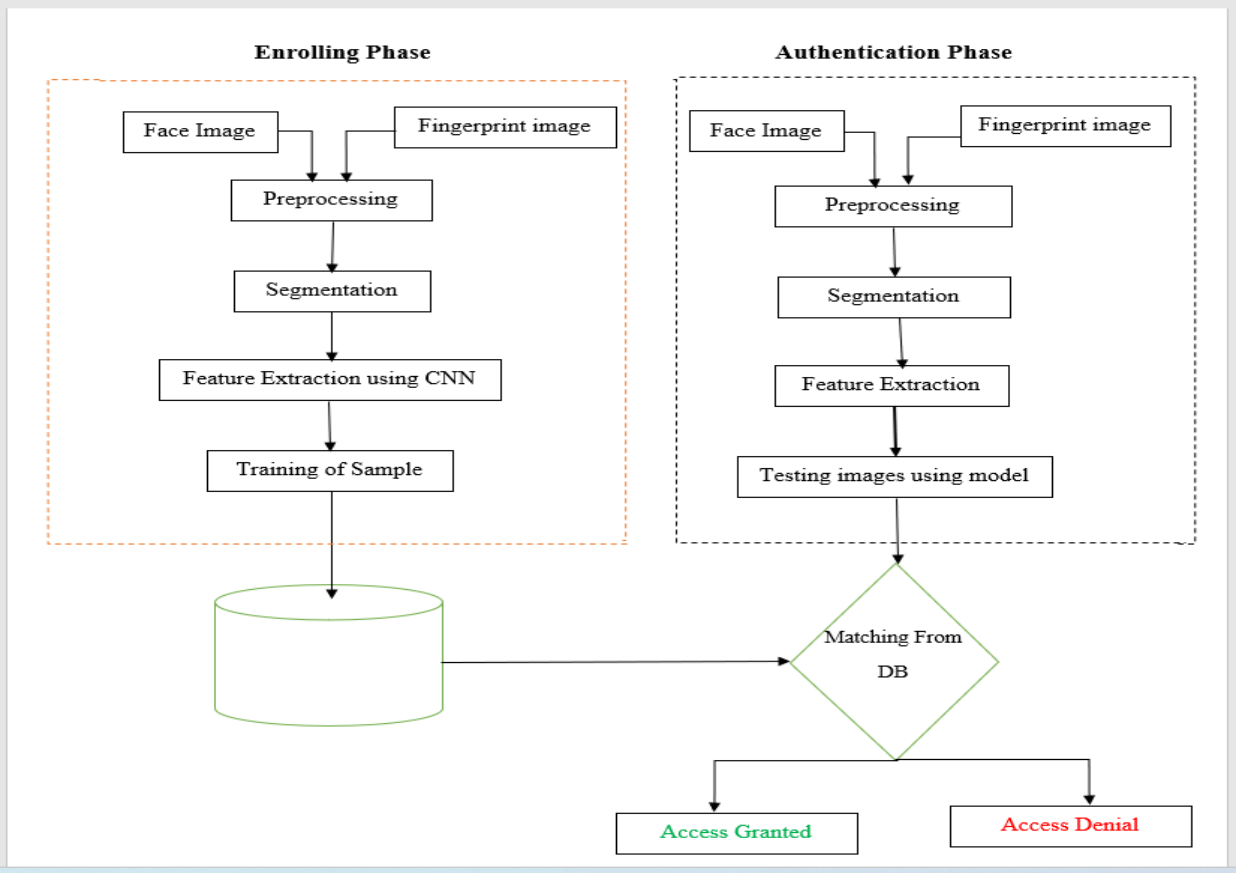


Fig. 1. Proposed Model Architecture

IV. Experimental Setup, Result, and Discussion

A. The Tool Used for the Study

In this research study software and hardware tool was used for conducting an experimental activity. Software tools like Anaconda navigation and Jupiter notebook for the code editor, open-cv library for capturing images and then image processing tasks, Tensor flow, and CNN algorithms for creating the proposed model.

Different hardware tools are also used for experiments. Raspberry Pi is for implementing and controlling the research result, a Pi camera for capturing the user's facial image, fingerprint sensor devices for capturing fingerprint images, and jumper cables for assembling edge devices with a raspberry pi controller. The following Fig.2 shows a highlight of the hardware tools used.

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Gergito Kusse***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC6
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

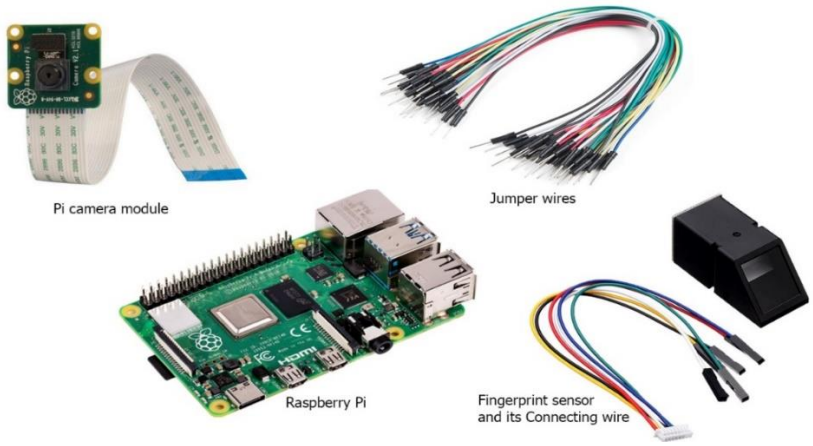


Fig. 2. Hardware tool used for the experiment

B. Experimental Setup

In the previous section tools used for experimenting were discussed in detail. In this section, experimental activities were discussed in the following subsections.

1) Assembling hardware tools: As presented in Fig. 3**,** Jumper wires were used to connect edge devices with Raspberry Pi, the fingerprint sensor has four/six-pin wire (ground, voltage, transmitter, and receiver) was connected to the corresponding pin of Raspberry Pi, camera module ware connected to the camera port of raspberry Pi, HDMI cable to connect Raspberry Pi to displaying desktop screen and the USB cable connects raspberry Pi with direct current to provide power.

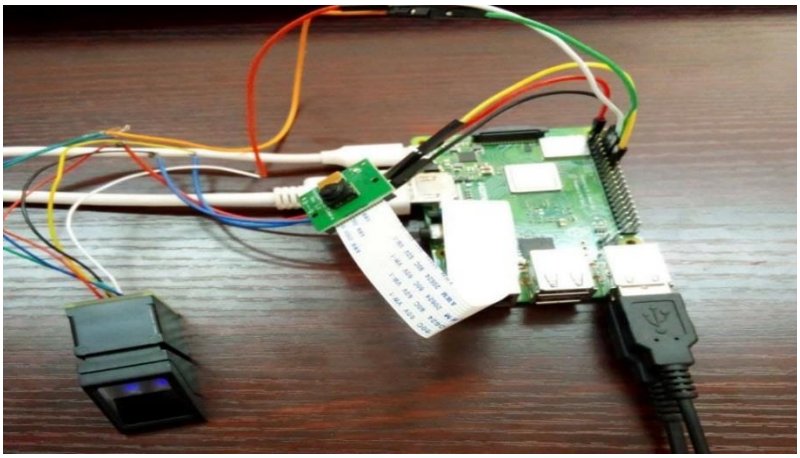


Fig. 3. Assembled hardware tools

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Gergito Kusse***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC6
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

C. Enrollment Phase

The main aims of the study were addressed in this enrollment phase. In this phase, how users' image was collected as a dataset of the study, image processing steps, and CNN layer were discussed in detail: -

1) Datasets (image acquiring): Datasets used in this research study were the image of the user's facial image and fingerprint image as presented in Fig. 4 and 5. Those images are captured by the Pi camera module and fingerprint sensor devices which means all the data sets used for the experiment were primary data. To get high accuracy in the proposed model prediction during the enrollment phase 50 users' face image with different (20) angle position was captured by the Pi camera module and two fingerprint images were captured by fingerprint sensor devices. The sample size of data is 50X20 = 1000 face images and 2X50 = 100 fingerprint images. The following Fig. 4 shows the collected data set of users.

Fig. 4. Sample dataset user's face image

Fig. 5. Sample dataset of user's fingerprint image

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Gergito Kusse***

2) Pre-processing: first activity of image processing is capturing the image as a dataset. The face region was detected and cropped then resized to 200 X 200 on the face image. Image enhancement and minutiae extraction was applied as a preprocessing task on the fingerprint image.

3) Segmentation: segmentation task on the face image is responsible for converting a colored image (RGB) into a grayscale image and then transforming the image into a numerical data array by using the NumPy library. The segmentation process in the fingerprint image was responsible to remove unnecessary or unwanted data from the image. And then ridge flow estimation and region of interest of minutiae were considered under this task.

3) Feature Extraction: The feature extraction process was done by using a supervised deep learning method called CNN. The collected dataset of the user's image was split into 70% of the dataset as a training dataset and 30% used as a test dataset. To train the model CNN passes the following four layers: -

*a) Convolution layer***:** In this layer, the preprocessed image with 200 X 200-pixel resolution was multiplied by 30 X 30 filter images magically generated by CNN. In this case, 1st filtered image output becomes 171 X 171.

b) Normalization/Activation layer: In this layer, non-linear functions called RELU were used to train the dataset and speed up the training process and reduce computational time.

c) Pooling layer: The main aim of this layer in CNN is to reduce the dimension of an image which highly probably reduces computational time and avoids overfitting of a proposed model. The max-pooling method was applied to a normalized image. To reduce the dimension of an image, 20 X 20 Max-pooling was applied. So, the first-round max-pooling result was 152 X 152 pixels.

d) Fully connected layer: The output of the pooling layer which is a 3D image was converted to a 1D image by applying the flatten method on the image. The output of this layer was used as the input layer for a neural network. The following Fig. 6 shows the summary of feature extraction.

D) Authentication Phase

The main responsibility of this phase is to check whether the captured face image and fingerprint was matching it from the created mode during the enrollment phase and then make a decision

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Gergito Kusse***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC6
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

based on the output result. In this authentication process, the first three steps of the image processing task are similar to that of enrolling phase, but the difference is that there is no need to train the captured image rather it tests and then matches it from the trained model. Another difference is that in the case of enrolling phase RELU functions were used as activation functions for training the model, but in the authentication phase Regression function as optimizer and SOFT-MAX were used as the activation function for classifying images to corresponding users.

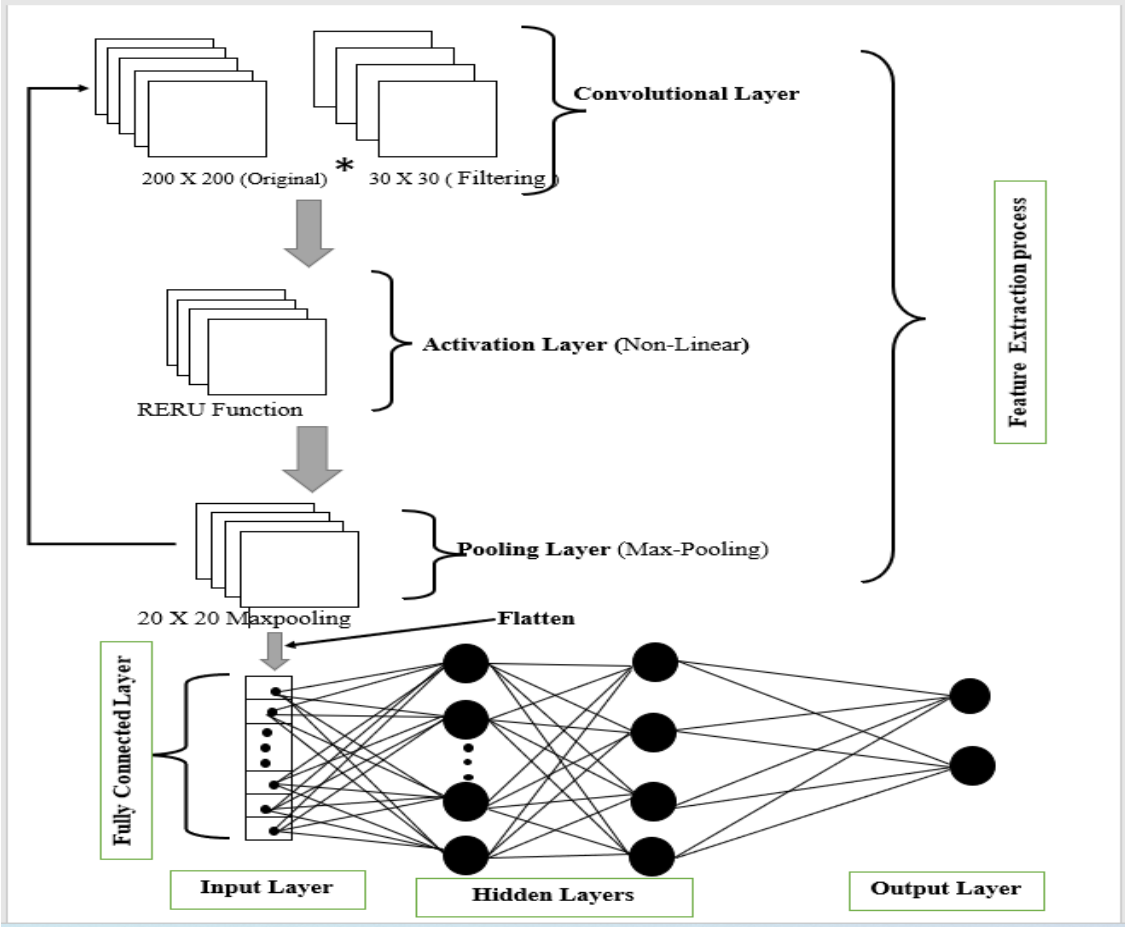


Fig. 6. Feature extraction using CNN

V. Conclusion

IoT system is a highly growing technology that improves the quality of our daily life. So, to ensure the physical security of IoT systems and their operating technology, multimodal biometric authentication systems were designed. In this research work, the unimodal and multimodal

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Gergito Kusse***

biometric system is discussed in detail after the multimodal system is implemented by using CNN algorithms on both face and fingerprint images. The Relu function was used as an activation function and a max-pooling method for dimension reduction on both images. The softMax function was applied for classification. Three parameters of performance analysis were considered (Accuracy, FAR, and FRR). The result shows that accuracy is 92% and 89% for the face and fingerprint respectively, FAR is 1.35%, and FRR is 1.5%.

Future works: From the results of the experiment, it shows that the accuracy of the fingerprint image is 89%, which still has scope to enhance. So, this research work may be extended for improving the existing accuracy of results or by adding another biometric system.

References

[1] M. Abomhara, "Cyber security and the Internet of things vulnerabilities, threats, intruder and attacks," *Journal of Cyber security and mobility*, vol. 4, no. 1, pp. 65-88, 2015.

[2] "TeachTarget," [Online]. Available: https://www.techtarget.com/searchsecurity/definition/biometric-authentication, 2022.

[3] S. Prabu, M. Lakshmanan & V. Noor Mohammed "A multimodal authentication for biometric recognition system using intelligent hybrid fusion techniques," *Journal of the medical system (Springer)*, vol.43, no. 249, p. 2, 2019.

[4] A. H. S. C. Ibrahim Omara, "A Hybrid Model Combining Learning Distance Metric and DAG Support Vector Machine for Multimodal Biometric Recognition," *IEEE Access*, vol. iii, no. 43, p. 3, 2020.

[5] M. T. M. B. a. N. C. M. Regouid, "Multimodal biometric system for ECG, ear and iris recognition based on local descriptors," *Multimedia Tools Appl*, vol. 78, no. 16, 2019.

[6] S. J. R. a. p. Norvig, “Artifitial Intelligent in moderen Approarch,” second edition, United stat of america, 2003.

[7] Y. B. Y. Lecun, "Deep Learning nature," vol. 521, p. 436, 2015.

[8] A. M. A. A.-A. Mohammed Ali Al-Garadi, "Servey of Machine and Deep Learning methods for IoT security," *IEEE Communications Surveys & Tutorials*, 2020.

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Gergito Kusse***

[9] D. V. S. Jasmeen Sharma, "Multimodal biometric authentication using face and fingerprint," *IOSR Journal of Engineering*, vol. 08, no. 4, 2018.

[10] S. V. a. C. Poellabauer, "Multimodal Biometric-based implicit authentication of wearable devices for the users," *IEEE Transactions on Information Forensics and Security*, 2019.

Received: *19 March 2022;* ***Revised****: 23 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*

Corresponding author- ***Gergito Kusse***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC7
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

DESIGN AND DEVELOPMENT OF A MODIFIED BIOMASS CHARCOAL PRODUCTION KILN

Sisay Wondmagegn Molla[1*], Mequannent Esubalew[2], Ambachew Balemual[3], Sahlu Mhriet Gela[4]
Tadelle Nigusu Mekeonnen[5], Wassie Adane Eshetu[6], Mekash Tesfaw Gezahgn[7]
[1,4,5,6,7] *School of Chemical and Mechanical Engineering, Woldia University, Woldia, Ethiopia*
[2]*Department of Chemical Engineering, University of Gondar, Gondar, Ethiopia*
[3]*Faculty of Chemical and Food Engineering, Bahir Dar, Ethiopia*
**Corresponding author: siswondmagegn23@gmail.com*

Abstract

This research was focused on the design and development of a modified biomass charcoal production kiln. Society uses an ancient and rudimentary method of charcoal production that has received little investigation and analysis. The conventional charcoal production process has several drawbacks and disadvantages in terms of rate of carbonization, quality, yield, pollution, labor, and land costs. This study aimed to design and develop a charcoal production carbonization kiln that would alleviate the mentioned problems. The following results found the moisture content as (2,0.89) %, the volatile matter (8.84,3.02) %, the fixed carbon content (81.09,91.42)%, the heating value (29.982,32.762)MJ/kg, bulk density (342.53,434.5)kg/m^3, shatter resistance(88.8,91.12)%, water penetration resistance (26.34,17.99)%, ash content (8.06,4.660)%, efficiency(16,31)%, and production time per cycle(3,5) days for conventional earth mound kiln and improved carbonization kiln respectively. From the result, the maximum shatter resistance shows well in mechanical strength, and high-water penetration resistance shows that the charcoal has better water absorption and a good heating value. The higher density shows that the volume is reduced due to the escape of volatile components and high fixed carbon content. Finally, the modified carbonization kiln yield was improved by 48.38%.

Keywords: ***Biomass, Carbonization charcoal, Design, kiln, Molecular weight***

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Sisay Wondmagegn Molla***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC7

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

I. Introduction

In developing countries, wood is the most common residential fuel. As most developing nations have an agriculture-based economy, biomass fuels continue to play a major role in both the residential and industrial sectors. A huge number of small, rural, and cottage businesses and commercial operations as well as the majority of rural and urban families, rely on biomass as their primary source of energy [2]. During the colonial period, farmers and landless laborers generated abundant charcoal for home consumption in developing nations in pit kilns (holes excavated in the ground) or mound kilns (piles of wood heaped on the ground and covered with dirt). Pit yields (weight of charcoal/weight of wood) range from less than 10 to 25 percent [1].

Various carbonization procedures have been used to produce charcoal for thousands of years across the world. Society employs an ancient and rudimentary method of charcoal production that has received little investigation and experimentation. We discovered during the field evaluation that the present charcoal manufacturing process is mound kilns (wood piles placed on the ground and covered with grass). However, these production systems are recognized to have several limits and drawbacks in terms of quality, yield, pollution, labor, and land costs. To address such issues, more efficient charcoal manufacturing methods must be developed[1].

When rubbed and handled, charcoal generated under poorly regulated carbonization conditions might be hard and brittle, or soft and crumbly. During kiln discharge and shipping, around 5 to 10% of such charcoal is typically reduced to fines and loss [3].

If wood is burned in the absence of oxygen, the chemical reaction is incomplete combustion with the creation of carbon monoxide[4],[5].

$$C + \tfrac{1}{2} O2 \longrightarrow CO$$

The average charcoal production output from static kilns might reach 35%, whereas the lowest charcoal production yield from an earth mound kiln may reach 10%[6]. The goal of this project is to enhance the carbonization kiln that is used to carbonize carbonaceous materials to generate high-quality charcoal. [3].

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Sisay Wondmagegn Molla***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC7
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

Fig. 1. Local charcoal making (earth mound kiln) and cover straw

II. Materials and Methods

A. Experimental Work

Various places were investigated to determine the disadvantages of conventional charcoal production. During the field evaluation, downsides were identified by seeing and interviewing the producers, as well as determining which type of carbonized kiln is best for producing high-quality charcoal depending on environmental circumstances and carbonized material shown in Fig. 2 and 6. Because bricks have a greater temperature resistance (7000 - 15000 ^{0}C), good corrosion resistance, availability, durability (6-10 years), and cheap cost, as well as ease of assembly, economy, fire resistance, rain resistance, and sun resistance. As a result, we use clay bricks as the primary building material for our small-scale carbonization kiln.

1) Conventional Charcoal Production: The conventional method was applied as shown in the Fig. 2

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Sisay Wondmagegn Molla***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC7
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

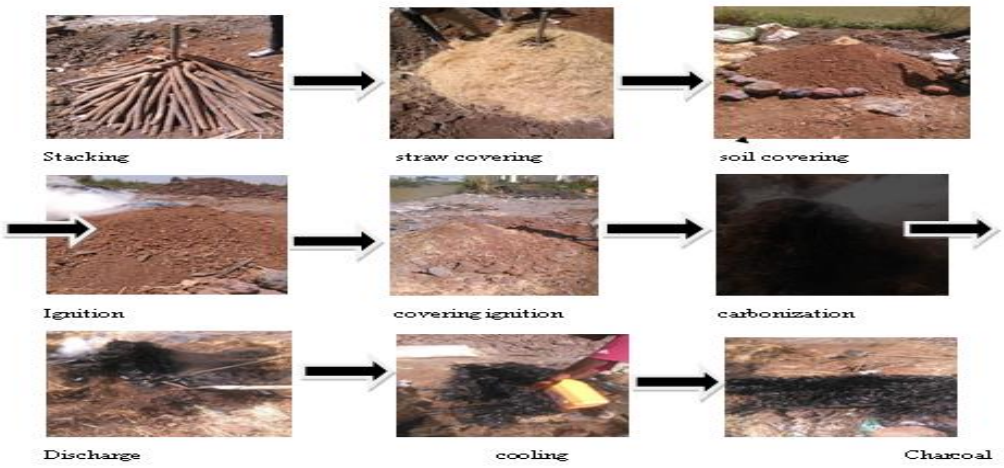


Fig. 2. Conventional earth mound kiln charcoal production experiment procedure

2) Improved Charcoal Production: The geometry was designed using solid work software (v18). The capacity of the kiln was 60kg and the geometry was designed based on this value. The construction of a carbonization kiln suited for local charcoal producers took into account several parameters, and it comprises the following elements. Wall thickness, smoke exit chimney, top cover (head), intake air vents, and anti–downdraft are all features of the carbonization chamber. The amount of air that enters the carbonization chamber determines how quickly biomass is carbonized. The air holes were placed around the outside of the carbonization kiln. It was controlled by placing air intake vents in strategic locations throughout the kiln. Because the carbonization process uses a finite amount of oxygen, we must restrict air entry by closing air input ports. The quantity of air supplied was managed by shutting and opening the air intake while keeping an eye on the smoke output. The amount of air was calculated to carbonize the wood based on the flow rate of air. Volume flow rate (Q) = A (area)* (v) velocity of air

$$Q = Axv \qquad (1)$$

The area of inlet air needed for the kiln was determined by using anemometer velocity determination (Testo420i) averagely measured was 0.05m/s. The individual area for each two sides air inlet and the opening area is circular, A= πD2/ hole number.

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Sisay Wondmagegn Molla***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC7
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

Table 1: Specification of Prototype Biomass Carbonization Kiln

	Component	Specification, cm	Material
1	Carbonization chamber	L=W=H=89cm	Clay brick
2	Wall thickness	12cm	Clay brick
3	Head of the kiln	R =44.5cm,L=89cm	Clay brick
4	Chimney	H=205cm,L=12cm,W=6cm	Clay brick
5	Inlet air vent	D=4.15cm	Clay brick
6	Loading and unloading door	H =88cm,W=40cm,	Metal sheet
7	Chimney cover	D =40cm,H=15.4cm	Metal sheet

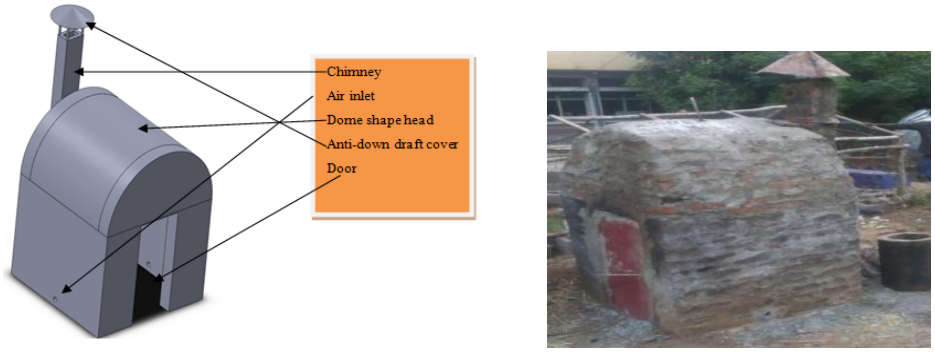


Fig. 3. (a) Model improved carbonization brick kiln. (b) Developed kiln

Fig. 4. (a) Wood charging. (b) Ignition

3) Performance evaluation: The performance of the kiln was performed using the following method tests the constructed kiln by producing charcoal.

Received: 21 March 2022; **Revised**: 28 February 2023; **Accepted:** 12 March 2023; **Published:** 30 April 2023.
Corresponding author- **Sisay Wondmagegn Molla**

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC7

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

B. Mass Conversion Efficiency

$$Ek = \frac{MC}{MW} x100 \quad (2)$$

Where Ek = kiln efficiency, MC = mass of charcoal produced, and MW = mass of wood put into the kiln

B. Bulk density

$$\rho = \frac{m}{v} \quad (3)$$

Where,

ρ = Bulk density of charcoal, kg/m3

m = mass of charcoal, (kg)

v1=Volume of charcoal inserted, m3

C. Shatter Resistance and Weight Loss

The charcoal with known weight was dropped on the concrete floor from a height of one meter.

1) Weight loss (%):

$$Wl = \frac{w1-w2}{w1} x\ 100 \quad (4)$$

2) Shatter resistance, (%):

$$Sr = 100 - \text{Weight loss} \quad (5)$$

Where: - w1 = Weight of charcoal before shattering (kg) and w2 is Weight of charcoal after shattering

D. Resistance to Water Penetration, %

Each charcoal sample was immersed in water for 30 seconds. The percentage of water gain was calculated as follows.

Water gain (%):

$$Wg = \frac{w2-w1}{w2} 100 \quad (6)$$

Where:-

w1 = Initial weight of charcoal (0.03kg) and w2 is the Final weight of charcoal

Heating Value (Hv)

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*

Corresponding author- ***Sisay Wondmagegn Molla***

$$HV = 0.3535FC + 0.1559VM - 0.0078AC \quad (7)$$

Where:-FC is fixed carbon content, VM is volatile matter and AC is ash content [7]

E. Fixed Carbon

The FC was calculated by subtracting the sum of percentage volatile matter (PVM), (PMC), and Percentage ash content (PAC) from 100.

$$FC\,(\%) = 100 - \%\ \text{of}\ (MC + VM + AC) \quad (8)$$

F. Volatile Matter

The dried sample left in the crucible was covered with a lid and placed in the furnace, maintained at 950ºC for 7 minutes. The crucible was cooled first in the air, put in aluminum foil, and weighed again. Loss in weight is reported as a volatile matter on a percentage basis.

$$(\%) = \frac{W2 - W3}{W2} 100 \quad (9)$$

Where, VM (%) = percentage volatile matter of charcoal, W2 = oven-dried sample weight of charcoal, and W3 =weight of the sample after furnace used.

G. Ash Content

The residual sample in the crucible was heated without a lid in the furnace at 750 ºC for five hours. The crucible was then taken out, cooled first in the air, then weighed in mass balance.

$$Ash\,(\%) = \frac{W2}{W1} 100 \quad (10)$$

Where, W1 = Initial weight of the oven-dried sample (g), W2 = weight of ash (g)

AC (%) = percentage ash content.

III. Results and Discussion

A. Comparison of Charcoal by Proximate Analysis

It was observed that the volatile matter of the charcoal produced in the earth mound kiln and improved carbonization kiln were 8.84% and 3.02% respectively. These show that the volatile matter of conventional earth mounds was higher than the improved carbonization kiln. Former literature [8] states that good charcoal has volatile matter below 30%. So, the results obtained agree with the literature. As the temperature increases the volatile matter decreases.

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Sisay Wondmagegn Molla***

It was observed that the average ash content of the conventional earth mound kiln and improved carbonization kiln was 8.06% and 4.66% respectively. The average ash content in the earth mound kiln was higher than the improved carbonization kiln. From the literature, the recommended good-quality charcoal contains an ash content of less than 5% [8]. Improved carbonization kiln has lower ash content than conventional earth mound kiln.

It is observed that the heating value of charcoal produced in the earth mound and improved carbonization kiln was 29.982 MJ/kg and 32.762 MJ/kg respectively. The heating value of the improved carbonization kiln obtained was higher than that obtained in a conventional earth mound kiln. The higher result obtained was due to the low moisture content and low ash value. Using equation (6) the above results were calculated and summarized in table 2.

Table 2: Average Proximate Analysis Value

No	Parameters	Earth mound	Improved kiln
1	Moisture content, %	2	0.89
2	Volatile matter, %	8.84	3.02
3	Ash content, %	8.06	4.66
4	Fixed carbon, %	81.09	91.42
5	Heating value MJ/Kg	29.982	32.762

B. Mass Conversion Efficiency

The percentage mass conversion efficiency shown in table 3 was used to compare the performance of an improved carbonization kiln with a conventional earth mound model charcoal-producing method. The findings demonstrated the mass conversion efficiency of two different charcoal manufacturing processes. The mass conversion efficiencies of the earth mound and the improved kiln were 31% and 16%, respectively. The production cycle per batch was 3 and 5 days for the earth mound and improved kiln respectively. The result from the earth mound kiln was 16% which agreed with the literature [1],[2]. This reduces the amount of charcoal product because, in the combustion process, the main output is heat [9]

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Sisay Wondmagegn Molla***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC7

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

When compared to mound kiln charcoal, enhanced carbonization brick kiln charcoal had a higher shatter resistance (91.12 %), indicating its appropriateness for transportation. Water sprayed directly on charcoal reduces its mechanical strength, making it easily breakable. They have strong shock, impact, handling, and transportation resistance, as evidenced by their high shatter (91.12 %) and water penetration (17.99 %) as shown in table 4. The cause for the lower Shatter resistance in the earth mound kiln (88.8%) was attributed to the spraying of cold water on the hot surface making the charcoal become cracked and easily breakable.

Table 3: Charcoal Yields and Production Cycle

Kiln type	Mass of wood (kg)	Mass of charcoal (kg)	Conversion ratio,%	Production cycle per batch
Conventional	60	9.6	16	4 day
Improved	60	18.6	31	5day

Table 4: Comparison of Charcoal Based on Physical Properties

No	Properties	Earth mound kiln	Improved carbonization kiln
1	Shatter resistance, %	88.8	91.12
2	water penetration,%	26.34	17.99
3	Bulk density kg/m^3	384.6	434.5

IV. Conclusion

Carbonization is a thermochemical process that involves heating biomass at a high temperature with a small quantity of oxygen to produce solid fuel, such as charcoal. The kiln was equipped with air vents around the perimeter, a carbonized material intake and exit, an anti-downdraft system, and an exhaust chimney. In this research, experiments were conducted to compare the performance of the enhanced carbonization kiln to that of the earth mound kiln. With regards to creating a solid fuel, the improved carbonized kiln was constructed from burnt clay brick and has been found to have greater conversion efficiency, high heating value, low moisture content,

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Sisay Wondmagegn Molla***

environmental adaptability, reduced labor force, non-seasonal intermittent, and low cost. In general, the yield or conversion efficiency of a conventional earth mound kiln is enhanced by 48.38 % when employing an improved carbonization kiln. In this, the improved brick kiln needed 2 days for carbonization and 1 day for cooling. An enhanced carbonization kiln had a bulk density of 434.5 kg/m^3 while a conventional earth mound kiln had a bulk density of 384.6 kg/m^3. This indicates that the improved carbonization kiln performs nearly twice as well as the traditional earth mound kiln. As a result, we concluded that an enhanced carbonization kiln is a viable option for carbonizing biomass in both local charcoal-producing communities and at home.

References

[1] Hassan Gomaa and Mohmed Fathi, “Simple charcoal kiln,” *Int. J. Acad. Res.*, pp. 1–74, 2000.

[2] D. M. Kammen and J. L. Debra, “Review of technologies for the production and use of charcoal ”. *Renewable Appropr. Energy Lab. Report.*, March 1, 2005.

[3] A. W. Toole, P. H. Lane, C. Arbogast, Jr., W. R. Smith, R. Peter, E. G. Locke, E. Beglinger, and E. C. O. Erickson, "Charcoal production, marketing, and use", *Forest Products Lab.*, Report no. 2213, July 1961.

[4] W. M. Lewandowski, E. Radziemska, M. Rims, and P. Ostrowski, “Modern methods of thermochemical biomass conversion into gas, liquid, and solid fuels,” *Ecol. Chem. Eng. S*, vol. 18, no. 1, pp. 39–47, 2011.

[5] J. A. Libra, K. S. Ro, C. Kammann, A. Funke, N. D. Berge, Y. Neubauer, M. Titirici, C. Fühner, O. Bens, J. Kern & K. Emmerich, “Hydrothermal carbonization of biomass residuals : A comparative review of the chemistry, processes, and applications of wet and dry pyrolysis,” *Biofuels*, vol. 2, no. 1, pp. 89–124, January 2011.

[6] A. Ogundele, O. Oladapo, and A. Aweto, “Effects of charcoal production on soil in kiln sites in Ibarapa area, South-Western Nigeria,” *Ethiop. J. Environ. Stud. Manag.*, vol. 5, no. 3, pp. 296–304, 2012. doi: 10.4314/ejesm.v5i3.12.

[7] R. A. P. Lomeda-De Mesa, A. N. Soriano, A. R. D. Marquez, and A. P. Adornado, “Study on the proximate and ultimate analyses and calorific value of coal blending between

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Sisay Wondmagegn Molla***

torrefied biomass from coconut (Cocos nucifera) husk and Semirara coal," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 471, no. 1, 2020.

[8] FAO, "Forest product conversion factors for the Unece Region," *Geneva Timber For. Discuss. Pap.*, vol. ECE/TIM/DP, p. 38, 2010, [Online]. Available at: http://timber.unece.org/fileadmin/DAM/publications/DP-49.pdf.

[9] A. M. Shakorfow, "Biomass . Incineration, Pyrolysis, Combustion and Gasification," *Int. J. Scie. & Res.*, vol. 5, no. 7, pp. 13–25, July 2016.

Received: *21 March 2022;* ***Revised****: 28 February 2023;* ***Accepted:*** *12 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Sisay Wondmagegn Molla***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC8

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

ADOBE WITH TERMITE MOUND SOIL FOR SUSTAINABLE HOUSE CONSTRUCTION IN GAMBELLA

Binaya Patnaik *[1], Gatbel Buony[2], Seshadri Sekhar T[3]

[1]*Dept. of Civil Engg., Gambella University. Gambella, Ethiopia*

[2]*Dept. of Civil Engg., Gambella University. Gambella, Ethiopia*

[3]*NICMAR-CISC, Hyderabad, India*

*Corresponding author: binaya7708@gmail.com

Abstract

The Gambella community in Ethiopia uses their indigenous knowledge of mixing termite mounds soil with locally available straws to build their mud houses. Mud houses constructed with termite mounds are comparatively stronger than those prepared with other soils, but they have severe durability issues due to shrinkage cracks that necessitate regular maintenance which is not affordable by many. This research paper presents technology intervention to resolve these issues faced by the community by introducing an alternative method of house construction called adobe. As part of this research 144 blocks of adobes were cast by using locally available materials and their performance was evaluated by conducting several strength and durability tests. The experimental results revealed that adobe prepared with termite mounds soil, 1.5% straws, and 2.5% of binder provides excellent strength and durability. The compressive strength was measured to be 2.6 MPa. Enhanced durability in terms of reduced shrinkage (17%), a low initial rate of absorption (0.29), and water absorption (0.26) were found in the adobe blocks. This indicates adobe is certainly the best solution to the existing houses' durability issues and a best-class sustainable solution for the construction of houses in Gambella, Ethiopia.

Keywords: ***Adobe, Mud Houses, Compressive strength, Durability, Straw, Chikka Bets***

I. Introduction

As per the indigenous knowledge of the Gambella community of Ethiopia, termite mound soils are the most suitable soils to build their traditional mud houses. Another perspective of the existing mud houses is the overconsumption of wood leading to large-scale deforestation thereby creating

Received: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published**: 30 April 2023.

Corresponding author- **Binaya Patnaik**

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC8
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

a negative impact on the environment along with soil erosion. There has been some research conducted in past to come up with Adobe blocks using locally available soil and straws along with a suitable binder [1],[2],[3] and the results are promising. So, in this research work an attempt has been made to make technical interventions to resolve the issues faced by the Gambella community regarding their house construction. This research work also aimed at identifying the suitability of termite mound soil, optimum percentage of binder, and reinforcing agents for preparing the adobes to achieve the maximum strength and durability from the adobe houses along with avoiding the shrinkage cracks. The issues related to mud houses have been presented in Fig.1.

Fig. 1. Major issues related to mud houses

II Materials and Methods

The materials used for this study were locally available termite mound soil, locally available straws, cement, and water. All the tests were conducted as per Indian standards.

A. Laboratory Tests on Termite Mound Soil and Local Straws

The soil used to prepare the adobe units were taken from the Nuer zone of Gambella town after consultation with the Gambella community for their most preferred soil to build houses as presented in Fig.2.

Fig. 2. Material procurement

Received: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published**: 30 April 2023.
Corresponding author- **Binaya Patnaik**

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC8
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

Soil tests were carried out by using ASTM standard procedures [4],[5] and soil classifications are identified according to the unified soil classification system (USCS) as presented in Fig. 3 below. The soil properties are a Natural Moisture Content of 19.21%, Air-dry Moisture Content of 15.25%, Specific Gravity of 2.64, Liquid Limit of 38%, Plastic Limit of 19%, Plastic Index of 19, Maximum Dry Density of 1.78gm/cc^3, and Optimum Moisture Content 15.5%.

Fig. 3. Soil and straw properties testing in the laboratory

The locally available straws are agriculture wastes plentily available in Gambella and used as the roof material for traditional houses. The experimental investigations carried out for the straw fiber are water content analysis, specific weight analysis, and water absorption rate analysis. The experimental test results are Cross-section (Circular), Length 30mm, Range of Diameter 0.2-1.2mm, Specific Weight 0.67g/cm^3, Natural Moisture Content 13.24%, Water Absorption in 5 minutes (g/min) 0.71, Water Absorption in 10 minutes 0.372(g/min), and Water Absorption in 1 hour 0.062(g/min).

The cement used for this research was PPC Dangote cement having a compressive strength of 32.5 MPa. PPC cement is highly durable, has less cost, and emits less carbon dioxide than OPC cement. Water is one of the major materials in the production of Adobe units. Water used in this study was free from all forms of contaminants, taste, and odorless i.e., in general, potable water.

B. Preparation of Adobe Units and Mix Proportions

All adobe units prepared for this research have a brick shape as presented in Fig. 4. One hundred forty-four (144) adobe units were prepared and cured by air-drying. The adobe unit samples were prepared with the dimension of 190mm x 90mm x 90mm. The mix of adobes has been presented in table 1.

Received: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published**: 30 April 2023.
Corresponding author- **Binaya Patnaik**

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC8
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

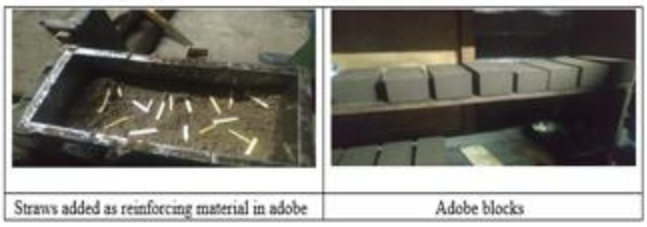


Fig. 4. Preparation of adobe units

Table 1: Mix Proportion of Different Adobe Mixes

Sr. No	Denotation	Soil (%)	Cement (%)	Straw (%)
1	A	97.5	3.5	Nil
2	B	97.5	3.5	0.5
3	C	97.5	3.5	1.5
4	D	97.5	3.5	2.5
5	E	97.5	3.5	3.5

C. Strength Tests

1) Compressive strength test: The compressive strength test was carried out to determine the amount of compressive load the adobe units can bear before fracturing and to describe the stress-carrying capacity of adobe units as shown in Fig. 5. The compressive strength test and stress-carrying capacity tests of adobe unit specimens were conducted after 28 days of air curing and drying.

2)Water strength test: The water strength test is the determination of the water strength coefficient for wet and dry compressive strength of adobe unit sample specimens. This test was conducted for all adobe unit sample specimens after 28 days of curing and air drying as presented in Fig. 6.

D. Durability Tests

1)Shrinkage test: The shrinkage test determines the volume change of adobe unit sample specimens before drying and after 28 days of dry curing. The volume of the adobe specimens was measured immediately after the casting of the adobes and allowed to dry cure for 28 days. The volume of the adobes was again measured after 28 days.

Received: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published**: 30 April 2023.
Corresponding author- **Binaya Patnaik**

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC8
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

2)Water absorption by capillarity: The water absorption properties of adobe are determined by conducting a water absorption test according to BS EN 772-11 as presented in Fig. 7.

Fig. 5. Compressive strength test on adobe block

Fig. 6. Adobe block for water strength test

Fig. 7. Adobe block for water absorption test

III. Results and Discussions

A. Soil Test Results for Optimum Stabilizer

Table 2 shows that the test results of the standard proctor test of soil-cement mix vary with cement amounts of 0%, 2.5%, and 3.5%. Therefore, the addition of 2.5% cement is an optimum value that will be used in adobe mixes because it has given maximum dry density.

Table 2: Standard Proctor Test to Find Optimum Amount of Cement

Mixes	Maximum Dry Density (gm/cc)	Optimum Moisture Content (%)
Soil	1.74	15.6
Soil + 2.5% Cement	1.78	15.1
Soil + 3%Cement	1.72	15.8

B. Compressive Strength Test Results of Adobe Units

From table 3, it can be clearly seen that with the inclusion of straws in the adobes, the compressive strength increases, and the maximum strength can be observed for Mix C (Soil+2.5% Cement+1.5% straw fiber). The compressive strength value required by international standards for

Received: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published**: 30 April 2023.
Corresponding author- **Binaya Patnaik**

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC8
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

traditional Mudbrick is 1 MPa and for Mix C it is 2.6 MPa. This implies that the locally available termite mounds soil and straws can be used for preparing adobe units for house construction.

Table 3: Compressive Strength of Adobe Units at 28 Days Curing Period

Sr. no.	Mix	Compressive strength in MPa
1	A	2.27
2	B	2.29
3	C	2.6
4	D	2.4
5	E	1.99

C. Water Strength Test Results of Adobe

Water strength test results of the different adobe mixes have been presented in table 4. The minimum permissible value of this coefficient is 0.5. The test results indicate that mix C (Soil+2.5% Cement+1.5% straw fiber) has the highest water strength value of 0.58. This indicates that the strength loss in adobes after exposure to wetting is lowest for Mix C.

Table 4: Water Strength of Adobe Units at 28 Days Curing Period

Sr. no.	Mix	Water strength
1	A	0.46
2	B	0.51
3	C	0.58
4	D	0.53
5	E	0.52

D. Shrinkage Test Results of Adobe

Shrinkage test results of the different Adobe mixes are presented in table 5. It can be clearly seen from the test results that with the increase in fiber contents, the shrinkage is reduced. This indicates that the locally available straws have a positive influence on arresting the shrinkage cracks.

Table 5: Shrinkage Test Results of Adobe Units

Sr. no.	Mix	Reduction in volume (%)
1	A	22.44
2	B	19.61
3	C	17.96
4	D	17.25
5	E	16.12

Received: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published**: 30 April 2023.
Corresponding author- **Binaya Patnaik**

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC8

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

E. Water Absorption Test Results of Adobe

Water absorption test results of the different adobe mixes are presented in table 6. It can be clearly seen from the test results that with the increase in fiber contents, water absorption is reduced. This indicates that the locally available straws have a positive influence on arresting the water absorption of mud blocks.

Table 6: Water Absorption Test Results of Adobe Units

Sr. no.	Mix	Absorption [Kg/(m^2 x min)]
1	A	0.46
2	B	0.52
3	C	0.44
4	D	0.26
5	E	0.32

IV. Conclusions and Recommendations

Based on the experimental investigations of this research, the following conclusions have been made.

- The termite mound soils have better strength compared to other soils because of the high calcium content which is released from the termite saliva.
- Cement is the most suitable binder for the termite mound soils for adobe preparation.
- The optimum percentage of the binder for the termite mound soil is 2.5% by weight.
- The optimum percentage of straw for the preparation of adobe is 1.5% by volume of the soil mass.
- The optimum combination of adobe constituent materials from a strength and durability perspective is ___soil, 2.5% cement, and 1.5% straw.
- The introduction of straws as reinforcing agents enhances the shrinkage resistance capacity and water resistance capacity of adobes.

The utilization of Adobe as building construction technology is cost-effective and would help in reducing the dependency on wood for the construction of mud houses thereby reducing deforestation.

Received: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published**: 30 April 2023.
Corresponding author- **Binaya Patnaik**

References

[1]. V. Sharma, H. K. Vinayak, and B. M. Marwaha, "Enhancing sustainability of rural adobe houses of hills by addition of vernacular fiber reinforcement," *International Journal of Sustainable Built Environment*, vol. 4, pp. 348-358, July 2015.

[2]. V. Sharma, B. M. Marwaha, and H. K. Vinayak, "Enhancing durability of adobe by natural reinforcement for propagating sustainable mud housing," *International Journal of Sustainable Built Environment*, vol. 5, pp. 141-155, Mar. 2016.

[3]. B. Patnaik, T. Gebreyesus, and G. Kassahun, "Sustainability of adobe structures – a review," *JETIR*, vol. 6, no.6, pp. 831-835, June 2019.

[4]. *Standard Test Method for Specific Gravity of Solid Soils by Water Pycnometer*, ASTM D854-00, Dec 27, 2016.

[5]. *Standard Test Method for Laboratory Compaction*, ASTM D698, June 10, 2000.

Received: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published**: 30 April 2023.

Corresponding author- **Binaya Patnaik**

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

DESIGNING A FRAMEWORK FOR CYBER PROTECTION BASED ON UNIQUE IDENTIFICATION TO IMPROVE THE SECURITY OF ETHIOPIAN SOCIAL MEDIA USERS OVER FACEBOOK

Basha Kesim[1*]

[1] Faculty of Computing and Software Engineering, AMIT, Arba Minch University, Ethiopia

*Corresponding Author: bashirkasim59@gmail.com

Abstract

The social media like Facebook is one of the prominent having 2.6 billion monthly active users. However, Facebook users pose different security threats by impersonation and spreading untrue information. Nowadays, there are numerous threats to social media such as Facebook in Ethiopia. Due to this problem, it is significant to design remedial solutions for such problems. This research study aims to establish a Unique-ID-based Cyber Defense Framework to enhance the security of Facebook users and inhibit the creation of fake profiles and impersonation by spammers. The researcher followed an exploratory with a constructive research design using surveys, and in-depth interview-based primary data analytics. The study concluded with a Unique-ID-based Cyber Defense Framework consisting of application and security layers with various critical components. In the proposed system, the Digital Residential ID issued for Addis Ababa residents is used to cross-check the user-provided data with the resident DB to check the authenticity of the user based on the country code. After that, a framework and its prototype are developed. The result of user acceptance test shows an optimistic answer i.e., 87% of respondents accepted the research outcomes as a positive contribution. On the other hand, 13% still have a dilemma to accept a new and innovative contribution for an enhanced Unique-ID-based Cyber defense system to improve the security of Facebook users. The study concluded by noticing every time a user attempts to create a Facebook account, the user will be asked to confirm his/her uniqueness. Also, they could be prohibited from establishing fake or multiple accounts.

Keywords: ***Country code, Cyber defense Facebook, Fake profile, Impersonation, Security Threat, Unique Id***

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

I. Introduction

Accessing information anywhere, any time, and in any condition without the restriction of location was one of the features of the 21st century. Social media is now among the most influential media for the transmission, dissemination, and exchange of information and knowledge. It is used by billions of users to network with other users [1] [2]. Social networking platforms such as Facebook, LinkedIn, and Twitter have become widespread channels of communication with the rapid growth of users. There are more than 3.81 billion active users of social media networks today. Of all social media, Facebook is the largest with 2.6 billion monthly active users. Users of the maximum social media network have more than 200 friends [3] [4]. In addition to its benefits, social media has several drawbacks including security risks. The key problem with social media is the presence of fake accounts and online impersonations [5], especially on Facebook. As there is a lack of effective identity-proving mechanisms, anyone can set up a fake profile in the name of someone else to post negative and offensive content through the account [6]. Fake accounts are created to access people's information and post fabricated content since not all Facebook users check and verify the accounts before accepting the request from them [2] [7] [8].

Social network operators use several authentication methods to ensure that the individual registered on the social network is a natural person. Methods such as CAPTCHA, recognition of friends' images, and multi-factor authentication are used [5] [19] [11]. On Facebook, with multiple profiles, a single user can represent his identity because there is a lack of an effective identity verification process [12]. Facebook currently serves mainly as a channel for hate speech, intolerance, and increased discrimination against a specific ethnicity, religion, or gender [11]. In Ethiopia, Facebook's spread of hate speech and disinformation has grown exponentially in a couple of years. In January 2020, there were 6.20 million social media users in Ethiopia, as described by the study of world internet statistics 2020. Facebook is, therefore, the most prevalent use, and more than six million people use Facebook in Ethiopia [13].

There is a lack of methods for checking the source, which means it is difficult to trace the identity of the account owner [14]. Currently, there is a lack of effective Facebook user virtual identity verification frameworks. By using this chance bad users create fake accounts and impersonate someone to disseminate fabricated information that is targeted and discriminates against

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

individuals or groups based on their ethnicity, religion, and gender. Ethiopia has also suffered from Facebook because it acts primarily as a channel for hate speech, intolerance, and increased prejudice against a specific race, religion, and gender. Thus, these issues are causing tension between governments and individuals. In 2016 the Ethiopian government blocked Facebook many times because it was causing extensive instability in the country. Because misinformation can spread quickly via Facebook, the government confirmed to block social media totally from the country to stop the spread of hate and ethnic cleansing propaganda messages. Therefore, this shows Ethiopia's internet control operates mainly outside of a formal regulatory framework by blocking the internet totally from the country. And this is not effective, efficient, or productive. For example, Brookings Institution's report shows that Ethiopia, between mid-2015 and mid-2016, lost t $9 million US dollars due to internet shutdowns.

Therefore, this researcher motivates the researchers to build a system that can improve the verification of user identity on Facebook by developing an improved framework for enforcing the users to create their accounts with their genuine information. The implementation of the unique identification of user identity on Facebook for account creation and login is addressed in this research paper.

II. Literature Review

Table 1: Review of Related Works with Critical Remarks

No	Authors	Significant Contributions	Critical Remarks
1	Michail Tsikerdekis and Sherali Zeadally [18]	The researchers tried to discuss how to decrease identity deception by securing social media design and applying psychological pressure to deceivers. To prevent deceivers, they recommended different techniques like	This paper tried to discuss how to decrease identity deception by securing social media design and applying psychological pressure to deceivers. To prevent deceivers, they recommended different techniques like biometric authentication is one of them. The study was very relevant to our paper. However, it failed to explain how to verify the authenticity

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

		biometric authentication is one of them.	of the user identity, especially for Facebook, to prevent fake or forgery account creation and they missed explaining how to evade social media problems
2	Nadir AI Naqbi, Nail Al Momani, and Amanda Davies [19]	This paper explored the influence of social media as a threat to national security-related issues like social, Economic, and political disorders. This paper suggested the community awareness	This paper is relevant to our study. This research explored Arab Emirates data to discuss how to decrease identity deception by securing social media design and applying psychological pressure to deceivers. To prevent deceivers, they recommended biometric authentication.
4	Amitvikram Nawalagatti [20]	This study discusses the adverse impact of social media on users' privacy and security. In this paper, researchers tried to explain that social media are not suitably monitored and accounts are not properly verified. The study revealed many threats created by social media and proposed solutions	This study was very focused and found interesting to our research. The solution proposed by this research is very shallow and does not provide any concrete solution to secure the users' privacy like creating a strong password by complex combinations of alphabets, characters and special characters along with strong authorization on network access etc.

III. Research Methodology

This research used a mixed research design, both exploratory and constructive research. And a mix of qualitative and quantitative methods for gathering the most critical and relevant evidence. Therefore, a structured questionnaire and In-depth interview were prepared and distributed among selected social media users, and interviews were conducted with INSA.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9

A. Data Collection Procedures

The summary of data collection methods from both primary and secondary data sources is described in the following diagram.

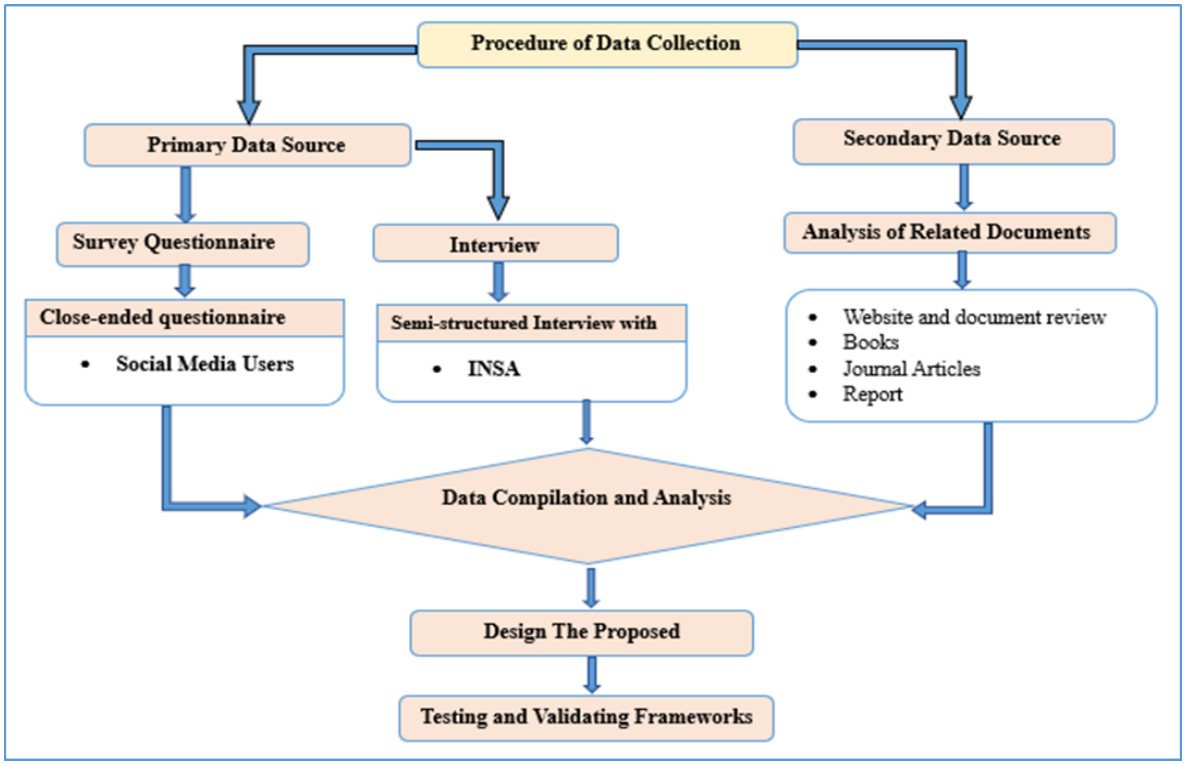


Fig. 1. Summary of data collection methods

B. Sampling Design

This study used the purposive sampling method. The person who does use social media in Ethiopia had the chance to be included in the study. This research study's sample size was 342. Three hundred thirty-eight (338) social media users were chosen for the survey questionnaire and 4 for the interview to collect the primary data.

IV. Data Analysis and Discussion

A. Demography of the Respondents

Fig. 2, shows the data of the respondents' demography like gender, age, occupation and education levels.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

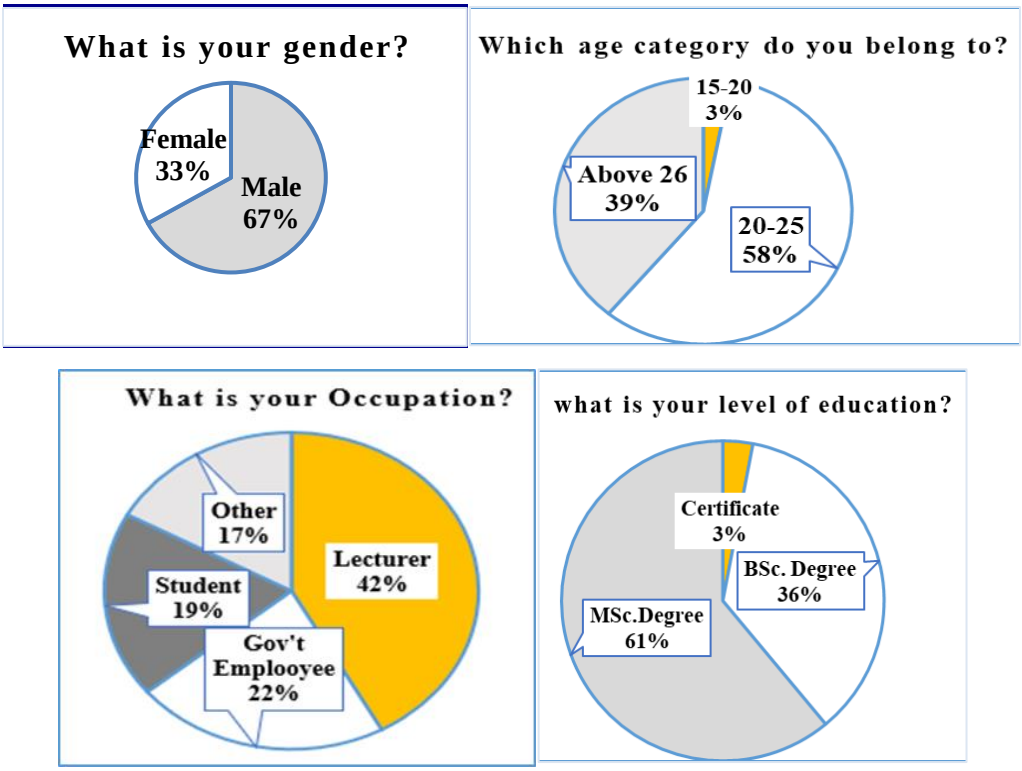


Fig. 2. Respondents' Demography Pie charts

How do you rate your participation in discussions on social media, especially Facebook?

Fig. 3 shows that the maximum number of users are not participating in the discussions on Facebook. So, this was due to some reasons.

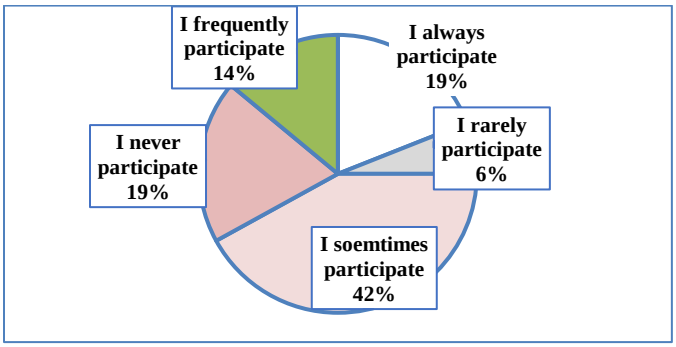


Fig. 3. Participation rate of respondents on Facebook**.**

If your participation in discussions is minimal, what prevented you from engaging in discussions on Facebook?

This question is a follow-up question to Fig.3 in which respondents are asked to reason out if their Facebook participation is minimal. Fig. 4 result implies that the reason why respondents'

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9

participation is minimal was that Facebook became the Media on which fake information can be propagated.

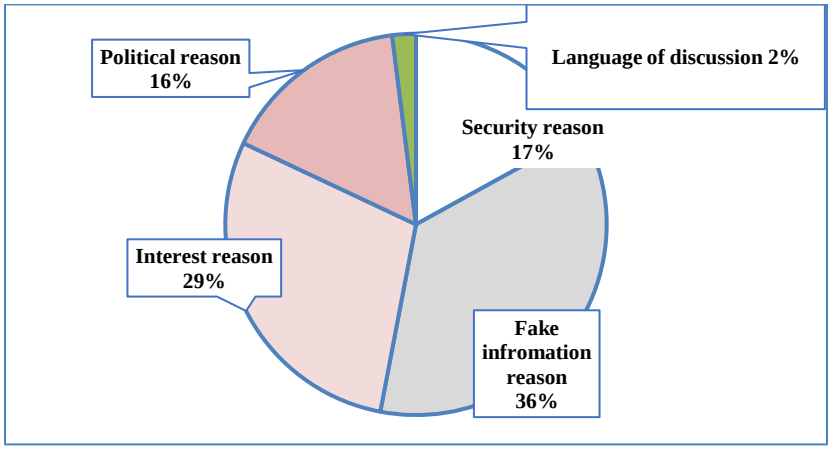


Fig. 4. Reasons that prevent the respondent from participating on Facebook.

What kind of information do you give to open a Facebook account?

As Fig. 5 shows the maximum number of respondents are not providing truthful information, and this specifies the existing security checking gap on Facebook. 62% (real/genuine) is greater than 38% (fake) but when we see the effect level of this amount, it is very big.

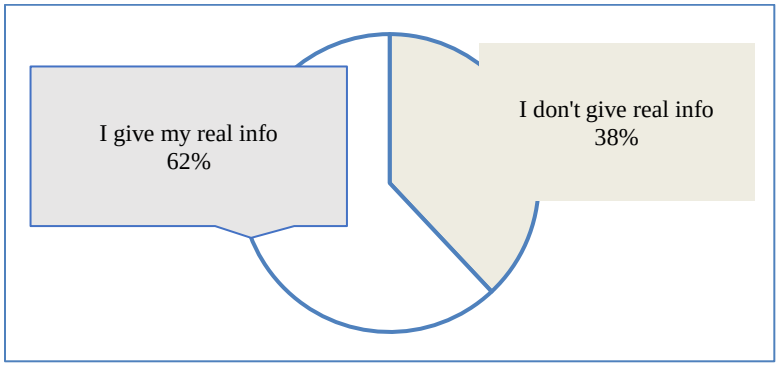


Fig. 5. Rate of access behavior of Facebook by Respondents

Do you trust the information you get on social media especially on Facebook?

The phenomenon on Fig. 6 confirms that the source of information propagated on Facebook was not trusted as verified and authenticated.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9

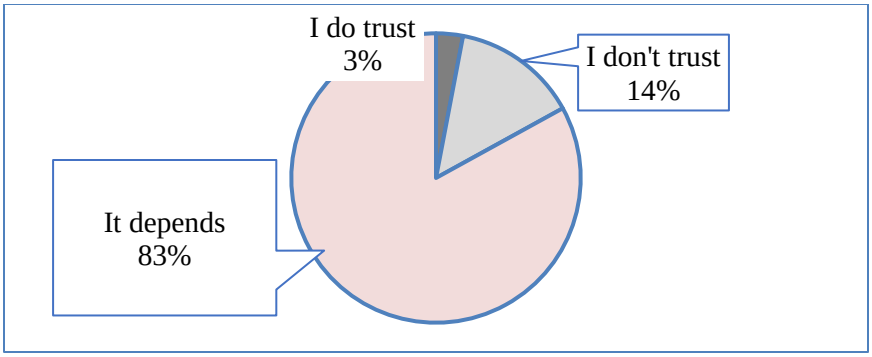


Fig. 6. The rate of trust in the information from Facebook

Can you believe that the current Facebook page verifies the real identity of the users?

The result on Fig.7 shows the existing Facebook page needs an urgent framework that enhances Facebook users' security by solving identity verification and authentication to prevent and avoid identity theft currently happening on the Facebook site. Matching the actual or physical identity of the users with digital identity was strictly recommended.

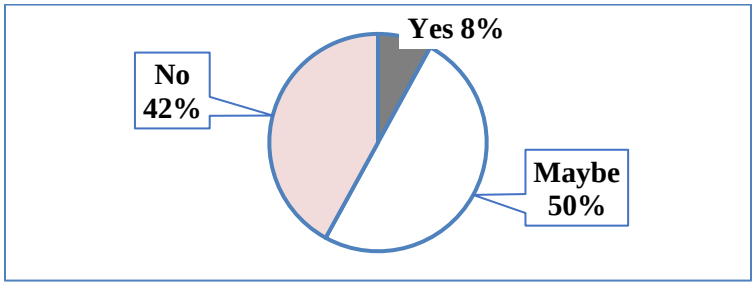


Fig. 7**. The rate of identity verification of Facebook.**

Can you believe that the required information to create an account on Facebook is enough to avoid fake accounts and duplicate account creation?

As Fig. 8 shows, the highest number of respondents responded with "**NO,**" which means the current Facebook page was easy for creating a fake or duplicate account as described in the literature review part.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

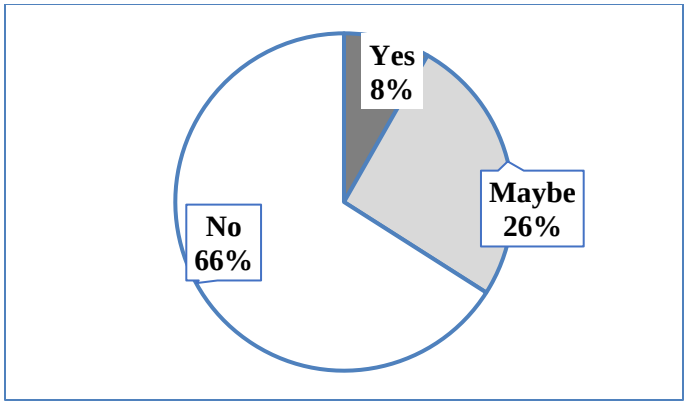


Fig. 8. Rate of respondents on duplicate and fake accounts inhibition way of Facebook

Can Facebook features such as anonymity and ease in having fake accounts, names and identities facilitate the discourse of hate speech as these features help the abusers go undetected and unpunished in our country?

The result on Fig. 9 shows that Facebook can be the instrument of hate speech dissemination and does facilitate and become a safe port for individuals, groups, and activists who intend to post toxic or offensive ideas. 61% of respondents have responded by agreeing.

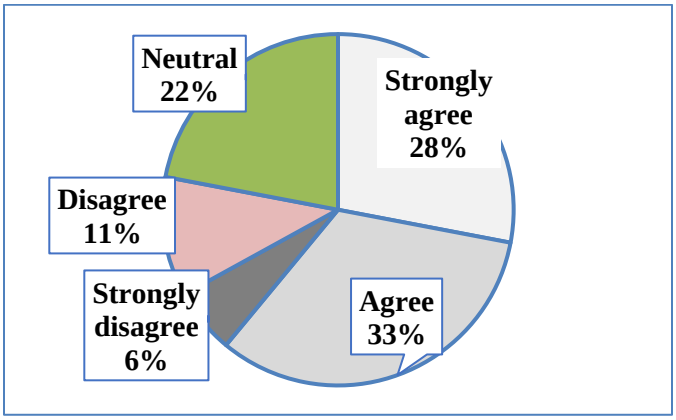


Fig. 9. Rate of respondents on the facilitation of hate speech by Facebook**.**

Currently, in our country, are there political activists with an interest to destabilize the country that are going to abuse Facebook features for getting speedy and vast audience connectivity?

Fig. 10 result specifies that there was a significant and vital need to develop an improved security framework that enhances the existing unique verification mechanism of Facebook accounts to satisfy the user's requirements. This can be done by bringing in a suitable alternative to control and prevent those who use Facebook for illegal activity from abusing Facebook features.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9

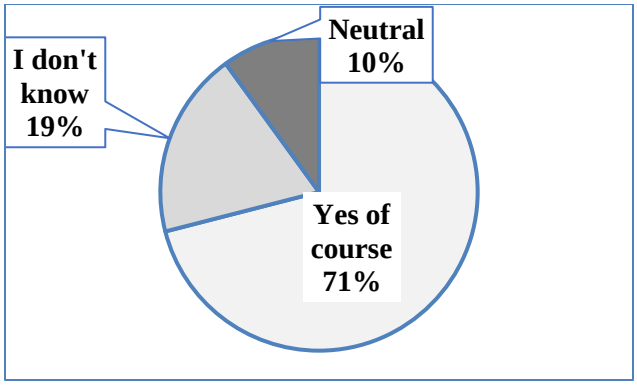


Fig. 10. Rate of respondents on the facilitation of political activists with an interest to destabilize the country by abusing on Facebook.

Why did the government block Facebook and other related media in the past few years?

The phenomenon on Fig. 11 indicates a strong need by Facebook users to develop an advanced framework that enhances the security on Facebook to prevent Facebook from becoming the media on which hateful information was propagated and to achieve stability and security for society.

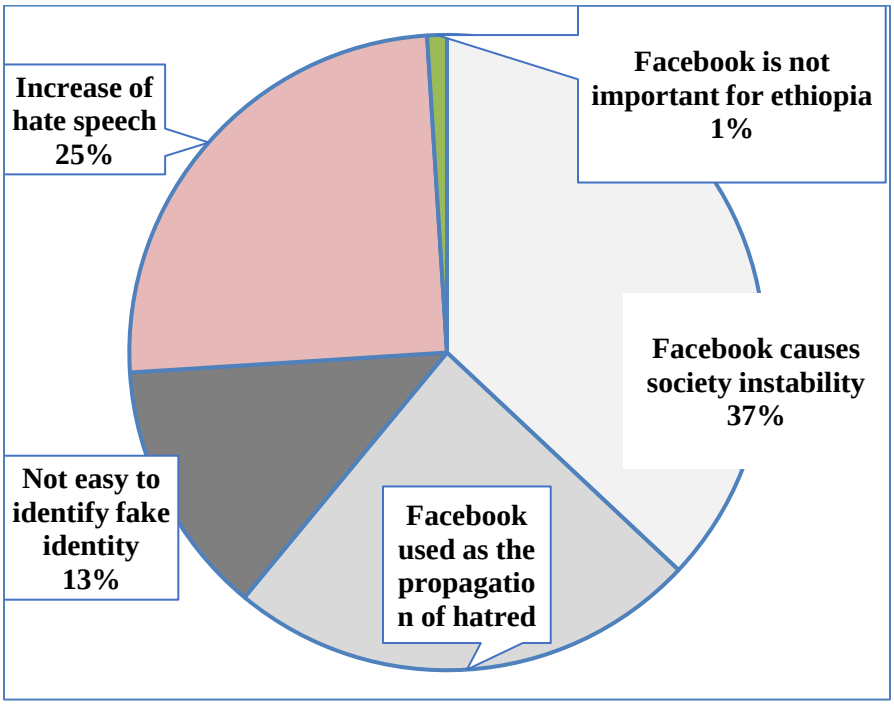


Fig. 11. Rate of respondents on the reason for blocking the Facebook site.

How often do you use Facebook?

As per the results on Fig. 12 below, the maximum number of people are using Facebook as media in which they post their everyday thoughts, feelings and activities.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9

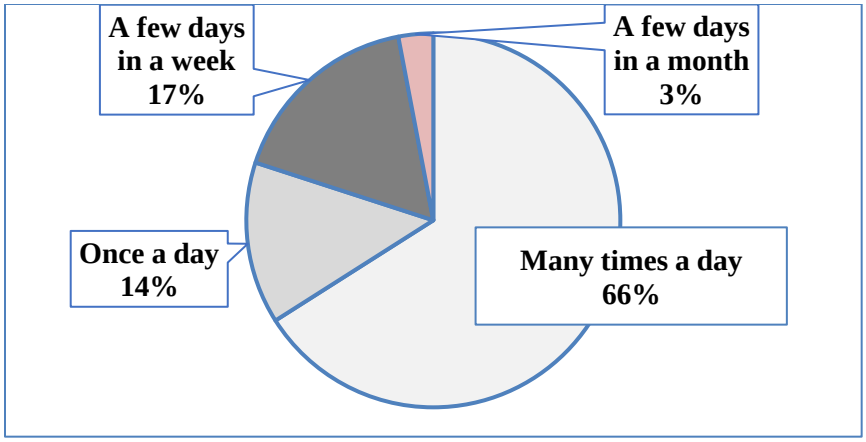


Fig. 12. The rate of how often the respondents use Facebook.

For what purpose are you using Facebook?

The phenomena on table 2 indicate that the maximum number of respondents are using Facebook for the excellent purpose that was appreciated. Still, some respondents use Facebook for illegal purposes like posting about political discrimination, posting information on touching others' religion, and negatively criticizing the government using the account created by Fake evidence.

Table 2: Purpose of Using Facebook By Respondents**.**

Purpose of using Facebook by respondents	Frequency (%)
To read news	32.65%
To know about a friend's life	25.49%
To share political, dissect	19.44%
To criticize the government	3.04%
To present political ideas	6.13%
Discuss the issue of cultural identity	5.10%
Commenting on people who are impacting my religion	8.15%

Do you check the source of the message before liking, reacting to, sharing or commenting on the post when using Facebook?

Fig. 13 indicates that the maximum number of users on Facebook accept the content without checking the truthfulness of the posted information.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

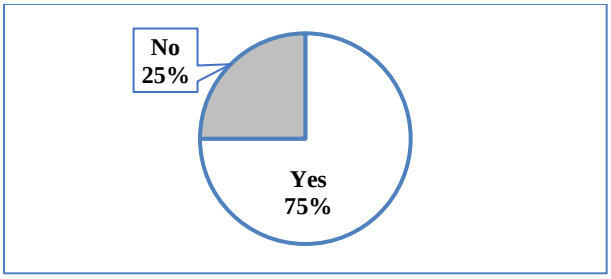


Fig. 13. Rate of respondents that are checking the source of content on Facebook

Do you agree that Facebook plays a substantial role in catalyzing hate speech, discrimination in society, increasing instability, and lack of peace in our county?

The phenomenon on Fig. 14 suggests a strong need for an urgent mechanism to restrict scammers from fake information dissemination on Facebook.

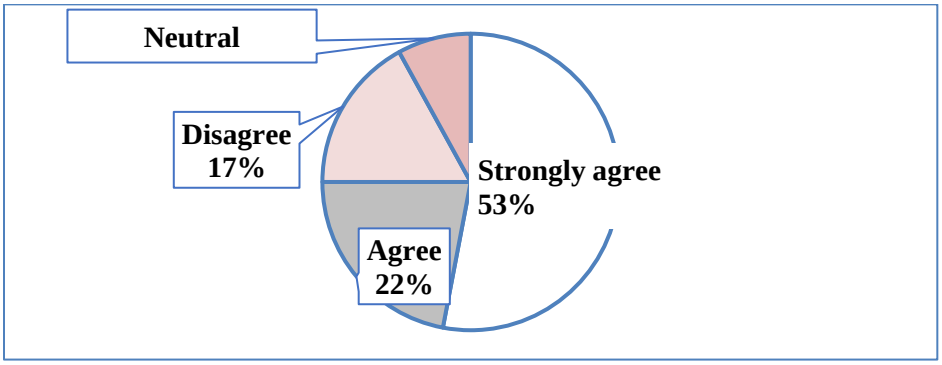


Fig. 14. Rate of Respondents on Facebook used as the publication of the dangerous idea

Would you need improved frameworks that enhance the security checking for verifying user identity on Facebook?

The percentage on Fig. 15 indicates that the highest number of respondents or the highest number of Facebook users need an urgent development of a better-quality regulatory and control framework to enhance users' security and to prevent Fake accounts and duplicate account creation.

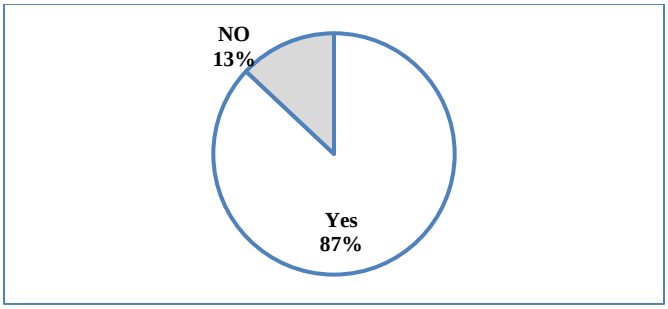


Fig.15. the need for improved security Frameworks on Facebook

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

Developing a Regulatory and Control Framework

Proposed Solution and its functionalities

This research paper introduces an innovative solution to protect and prevent creating a fake profiles, duplicate or redundant accounts, and impersonation. This research study presents a new concept to identify whether the users are providing factual personal information uniquely or not. The items that can be used to verify the user's identity should be unique.

V. Results

Creating a Profile on Facebook

First, the user accesses Facebook sites via the internet and provides the information on the registration form. In addition to the regular information previously provided by the users in this framework, two attributes are added to check whether the users were filling the registration form with the actual evidence on their digital residential ID card database in the country or not. After finishing filling out the registration form, the users send the data to the Facebook server by clicking the button. Secondly, the Facebook server's data can be validated before allowing the user to create the accounts. The server-side authentication and verification were done to prove the data provided by the users. The data provided by the user will be crosschecked from the digital residential ID card of the country to verify whether the persons with the received personal information were in the database or not. It was done by using a unique ID as a primary key and country code to identify the location from which the user was creating accounts. This takes place every time a new user tries to create an account on the Facebook server. Generally, as everybody cannot provide an identity card independently, the institutions that have authority are responsible for giving proper unique identifiers.

Login to Profile

The login process was similar to the existing one.

Significant Components of the Proposed Framework

Fig. 16 presents the general framework of the Facebook page. Generally, the framework contains two sides, the User side, and the Server side, and in these layers, there are various components with different activities. These are:

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

Users: The persons who came to the Facebook page to access and use it every day.

Internet: is the network of network that allows the world to interconnect and communicate together

Facebook website: a social networking site that makes it easy to connect and share with family and friends online.

Sign Up Form: It is a form used to create a new Facebook account user using a name, country code, phone, UNIQUE ID, gender, birth date, nationality, and password.

Facebook server: Facebook server is the place where Facebook stores its users' data.

Server-side Authentication and Verification: it's the place where the proofing takes place.

Authentication Failed: The response message that responds if the cross-check between the user's personal information during account creation and the resident information in the digital residential ID card database does not match.

Authentication Success (Ok): The response message that responds if the cross-check between the user's personal information during account creation and the resident information in the digital residential ID card database match.

Verification SMS: it is the verification code usually known as One-time Password (OTP) that is sent to the phone of the user who tries to create a new Facebook account to confirm the owner of the profile.

Middleware: it is a system software that enables and simplifies the integration of components developed by multiple platforms i.e., resolves the issues of heterogeneity of the systems.

Addis Ababa City Digital Resident Database: The database includes digital information about any persons that live in Addis Ababa.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC9
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

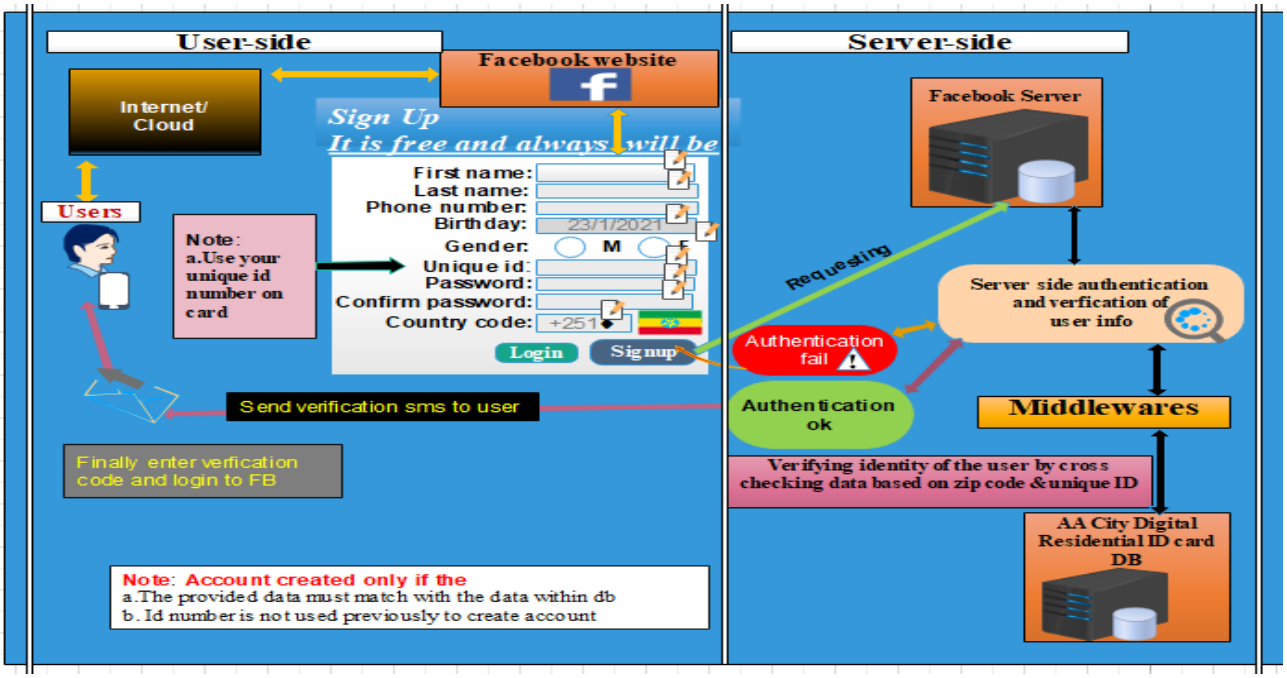


Fig. 16. Unique-ID-based cyber defense framework for enhancing the security of Ethiopian Facebook users.

Prototype Development

In this part, the developed system framework's functional prototype was presented. Fig. 16 shows the screenshots of the demonstrated prototype.

Design Description of a Prototype for Mobile Devices

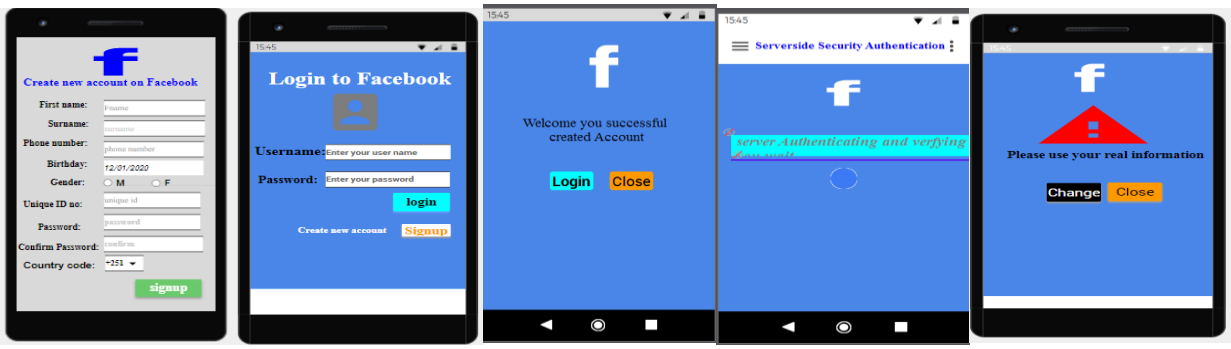


Fig. 17. Facebook login through Mobile on Prototype

Received: 19 March 2022; **Revised:** 27 March 2023; **Accepted:** 2 May 2023. **Published:** 30 April 2023.
Corresponding author- **Basha Kesim**

VI. Conclusions

The main objective of this study was to identify and analyze, from a security perspective, the deficiencies and challenges of the current state of social media, particularly in Facebook, and then develop a regulatory and control framework to improve the security checking technique for Facebook users. After primary data was collected using a survey and interview and analyzed together with secondary data, the researcher concluded that there are problems in Facebook user identity authentication and verification in our country and worldwide. Then the researchers' domain professional interview and social media users' survey responses concluded that the problems and challenges are destructive issues and require earnest and robust solutions by adding some functionality to the current Facebook user framework to save the generation from the act of unethical and malicious usage. The finding shows that the current Facebook user authentication and verification are vulnerable. They need strong attention to improve through scientific solutions. The current practices' challenges are identity theft, fake information dissemination, hatred of information propagation, impersonation, etc. In general, the recent Facebook security practices are found to be insecure. There is a lack of user identity proofing. It was used as the media in which fake accounts can be easily generated and used to disrupt society.

Based on the findings, the researcher designed the Unique-ID-based cyber defense framework for enhancing the security of Ethiopian Facebook users. The proposed Frameworks use a unique item or attribute representing only one person like the country code and UNIQUE ID number issued for the residents. This could be tremendous and significant to resolve the issues mentioned above and challenges with immediate effect on ground reality. Generally, this new framework that uses the unique user attribute, UNIQUE ID number on digital residential ID by the city and country code of the country, can restrict the user from creating a fake and duplicate account and impersonation problem via cross-checking the user-provided data with already stored data on the city database. The newly developed framework to enhance Facebook users' security by checking can do this task and ensuring that only verified users could be able to create an account and that user who provides unreal or fake information cannot create Facebook accounts. In the future, the researchers can focus their attention on user data security and privacy issue and come up with additional items that uniquely identify the users. Additionally, it is also recommended that upcoming researches have

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

to focus on the more profound and broader inquiry of preventing identity theft happening by wrong Facebook users locally and worldwide.

References

[1]. A. G. D. S. Asres. K, "Automatic surveillance and control system framework-DPS-KA-AT for alleviating disruptions of social media in higher learning institutions," *Journal of Computer and Communications,* vol. 08, no. 01, pp. 1-15, 2020.

[2]. M. Smruthi and N. Harini, "A Hybrid Scheme for detecting fake accounts in Facebook," *International Journal of Recent Technology and Engineering (IJRTE),* vol. 7, no. 5, pp. 213-217, February 2019.

[3]. L.S. Wickramaarachchi, et al," Bio-metric social media network secure," *International Journal of Scientific and Research Publications (IJSRP),* Volume 6, Issue 4, April 2016.

[4]. D. Brian, "Social network usage & growth statistics: how many people use social media in 2020? ," *Backlinko LLC,* August 12, 2020.

[5]. D. A. M, " Prevention technique for creating fake profiles and accounts on websites," *An international journal of advanced computer technology,* vol. VII, no. X, pp. 2826-2830 (5 Pages), 31 October 2018.

[6]. D. G. Yazan. B, "Integro: leveraging victim prediction for robust fake account detection in large scale OSNs," *Computers and Security,* vol. 61, pp. 142-168, 1 8 2016.

[7]. D. E. Katharina. K, "Fake identities in social media: a case study on the sustainability of the Facebook business model, "*Journal of Service Science Research,* vol. II, no. 4, pp. 175-212, 31 December 2012.

[8]. J. S. Memoona.S, "An automated framework for finding fake accounts on Facebook," *International Journal of Advanced Trends in Computer Science and Engineering,* vol. 7, no. 2, pp. 8-17, February 2018.

[9]. A. R. Gupta, "Towards detecting fake user accounts in Facebook," *SEA Asia Security and Privacy Conference 2017, ISEASP 2017,* vol. 1, pp. 1-6, 2017.

[10]. A. a. M. Mohammadreza.M, "Identifying fake accounts on social networks based on graph analysis and classification algorithms," *Security and Communication Networks,* vol. 1, no. 5923156, p. 8, 2018.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

[11]. M. R. Fire, "Online social networks: threats and solutions," *IEEE Communications Surveys and Tutorials*, vol. 16, no. 4, pp. 2019-2036, 2019.

[12]. H., M. Meligy, "Identity verification mechanism for detecting fake profiles in online social networks," *I.J. Computer Network and Information Security*, vol. 1, pp. 1-3, 2014.

[13]. S. Kemp, "Digital 2020: Ethiopia", *Datareportal.Com*, 17 February 2020.

[14]. H. N. Sibhat, "Spreading Hatred a study of Facebook in Ethiopia," *Global Media Review (GMR)*, vol. 1, no. 2, pp. 1-10, 2018.

[15]. M. Armstrong, "Social media reports," *statista.com*, Feb. 3, 2020.

[16]. H. B. C. A. K. G. Schroeter, "Creating safe and trusted social networks with biometric user authentication," *International Conference on Ethics and Policy of Biometrics.*, vol. 6005 LNCS, no. 03029743, pp. 89-95, 4 Jan 2010.

[17]. J. Nicas, "Why can't social networks stop fake accounts?", *The New York Times*, December 8, 2020.

[18]. Al Naqbi, N, Al Momani, N. Davies, "The influence of social media on perceived levels of national security and crisis: a case study of youth in the United Arab Emirates." *Sustainability*, 2022.

[19]. M. Tsikerdekis and S. Zeadally, "Detecting and preventing online identity deception in social networking services," *IEEE Internet Computing*, vol. 19, no. 3, pp. 41-49, May June 2015.

[20]. Amitvikram N, "Analysis of security and privacy issues in social media," *International Journal of creative research thought*, 2022.

Received: *19 March 2022;* ***Revised:*** *27 March 2023;* ***Accepted:*** *2 May 2023.* ***Published:*** *30 April 2023.*
Corresponding author- ***Basha Kesim***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

SYNTHESIS AND CHARACTERIZATION OF MECHANICAL AND PHYSICAL PROPERTIES OF FALSE BANANA (ʾ ƏNÄSÄTƏ) FIBER REINFORCED COMPOSITE MATERIAL

Belay Taye Wondmagegnehu[1*], Zewdie Alemayehu[2]

[1,2] School of Mechanical and Automotive Engineering, Dilla University, Ethiopia

[*]Corresponding Author: belaytaye1@gmail.com

Abstract

The use of environmentally friendly materials has recently been promoted due to increased awareness of environmental issues. To offer a better world for future generations, we must decide what we will utilize and serve today. When resources and products reach the end of their useful lives, resource preservation and degradation become issues. Biodegradable products manufactured from renewable resources address these issues. This research aims to develop a biodegradable resource of false banana (ʾənäsätə) fiber as reinforcement with polyester resin composite material manufactured by hand lay-up method at room temperature. The mechanical and physical properties of the produced sample were investigated. include tensile, flexural, impact strength, and water absorption. The fiber surface was treated with NaOH alkaline in distilled water solution. In composites, the fiber orientations were 0^o, 90^o, 45^o/-45^o, 0^o/90^o, and chopped, at 40% fiber volume fraction. The sample's production process was performed successfully. A chopped sample is an easier manufacturing process relative to the other. As the result, 0^o fiber direction scored the highest tensile strength, which is 181.41MPa. In the flexural and impact strength test, a 90^o oriented fiber was observed with the highest value, which is 81.43 MPa and 9.75 joules, respectively. The samples were immersed in distilled water until saturated. The highest percentage of water absorption was 45^o/-45^o oriented fiber. Many researchers have recently shown interest in natural fiber composites material for aerospace and automotive applications, such as aircraft radomes and interior cabin components, as well as remarks on natural fiber composites' future trends and problems. This article provides readers with a positive perspective and piques industry players' interest in the potential of using natural fiber composites in aerospace applications to improve current aerospace material performance, particularly in terms of lightweight and environmental sustainability.

Keywords: ***Composite, Fiber, Manufacturing, Matrix, Reinforcement, Sustainability***

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*

Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

I. Introduction

A composite material is made up of at least two materials that work together to provide properties that are better than the sum of their parts. Composite materials are used for parts mostly because of their weight savings and relative stiffness and strength. New products, processes, and applications are constantly being developed in the composites industry, such as the use of hybrid virgin and recycled fibers, as well as faster and more automated manufacturing. Like all engineering materials, composites have specific strengths and limitations that should be considered during the specification process. However, the ability to adjust the combination of reinforcement and matrix to satisfy the necessary final properties of a component has been the major driving force behind the production of composites. Fiber extraction has been done from ʾənäsätə (False banana), sisal, jute, and banana for making new environmentally friendly and biodegradable composite materials (these composites are called ‘Green Composites' for some reason) [1]. Recent research in natural fiber composites has resulted in a major change in renewable-source fabrics and increased support for global sustainability. These natural fiber composites possess moderate strength and thermal stability when they are recyclable, but they need specific application deals with particular places.

The need for renewable fiber reinforcement composites was increased in the last decade. The literature contains several studies on the manufacture of composite boards using particles or fibers from a different source and synthetics binder for bonding the fibers. Composite materials focused their attention on a lightweight natural fiber composite to create economical and lightweight engineering applications. Natural fibers were found in large amounts in nature, and their biodegradability features, their contribution to global environmental sustainability, the fact that they are economical, and have a good balance between mechanical properties and lightweight makes them preferable [2]. The treatment of composite materials is aimed at improving the mechanical properties of alkali-treated fabric composites compared to untreated fabric composites [3] [4]. The effect of fiber concentration and fiber size was conducted on mechanical properties. According to the result, small-size rice husk fibers have maximum tensile strength, and large-size rice husk fibers have a minimum tensile strength. The composites were prepared by the hand layup method [5]. The Fourier transform infrared spectroscopy spectra analyzed the corresponding peak

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

of cellulose fiber and Urea Formaldehyde resin composite for a mechanical property of compressive strength and water absorption test, and it was found that fiber loading increased the mechanical strength of composites up to 30% of fiber loading. Additionally, the cellulose fiber loading is increased while the water absorption of the composite increases. Because of this, the composites were more biodegradable and eco-friendlier [6]. The effect of alkaline treatment of soaking time on the natural fiber surface and the mechanical property of tensile strength was presented [7]. Fiber dispersion was identified as a major factor influencing the characteristics of short fiber composites and a particular challenge for Natural Fiber Composites (NFCs), which commonly have hydrophilic fiber and hydrophobic matrices. The use of longer fibers can increase their tendency to agglomerate. Good fiber dispersion promotes good interfacial bonding by reducing voids by ensuring that fibers were completely surrounded by the matrix [8].

This paper explored the technical properties of a new product produced from ʾənäsätə fiber. The product was tested to determine its usefulness as new composite material and analyze its mechanical characteristics (such as tensile strength, impact strength, and flexural strength) to the convenient production of eco-design methodology based on the inherent product of ʾənäsätə fiber, which is extremely abundant in South Nations Nationalities and Peoples Regional State, Ethiopia.

II. Research Methodology

The hand lay-up technique is the easiest way to process composites. This approach has a low infrastructure requirement as well. By using this technique, samples were manufactured and their mechanical and physical properties were analyzed. ʾənäsätə fiber as reinforcement and unsaturated polyester resin as a matrix were utilized as a composite material.

A. False Banana (ʾənäsätə) Fiber and Preparation

ʾənäsätə plant is used to produce foods like *'qoč'o'* and *'bula'*, especially in the southern region of Ethiopia. ʾənäsätə fiber is extracted in the process of preparing food as shown in Fig. 1. The false banana plant does not require very large rainfall and grows in tropical countries at an elevation of 1000m-1600m. It requires a warm climate. The lengths of the strands vary substantially depending on the fiber's particular source and treatment during fiber extraction. Fiber strands from the middle sheaths can be as long as 15 ft or more if stripped from the whole length of the sheaths, as in hand or machine stripping; normal length ranges from 3 to 15 ft [9]. Polyester resin is used as a matrix.

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

This resin is used as a critical matrix material for a wide variety of applications [10]. Alkaline treatment is one of the most used treatments of natural fibers when used as reinforcement in thermoplastics and thermosets. In this study, sodium hydroxide (NaOH) was chosen because of its low cost and effectiveness [11],[12]. ʾənäsätə fiber is used in Ethiopian house construction for an interior part by mixing with gypsum. Therefore, based on its properties, it is chosen for the production of composite material because it has high mechanical strength and availability. The physical properties of the fiber are as follows: - a diameter is 0.2-0.26mm, Density is 1.38g/cm^3, and specific gravity is 0.9.

Fig. 1. Fiber production, A) Plantation, B) Fiber production, and c) Dried fiber

Sample Preparation Method

The preparation of this composite material utilized false banana (ʾənäsätə) fiber and polyester resin. The size of the molding profile was 350mm in width, 400mm in length, and 4mm in thickness prepared by cast iron. NaOH solution was used for fiber surface treatment. After immersing the fiber for 24 hours, it was dried by sunlight, and the fiber orientation was prepared as shown in Fig. 2. Then, the release agent (wax) was coated on the mold surface to prevent the polymer stitched on the surface. Fibers were cut and positioned as per the size of the mold in the form of a chopped strands, 0^0, 90^0, 45^0, and $0^0/90^0$ as shown in Fig. 3. The liquid polyester resin was then carefully combined with a hardener in a 10:1 ratio based on a manual prescription of hardener and poured onto the reinforcement board. The resin was uniformly spread by using a roller brush; it is used to remove air and excess matrix. The thickness of the composite panel was 4±0.15.

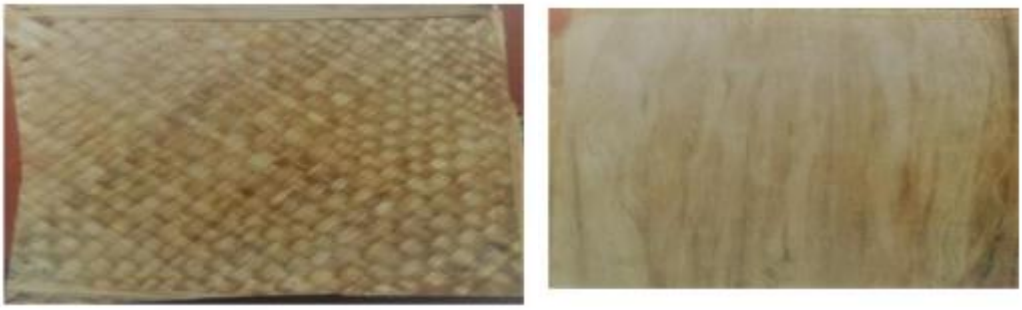
Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

a b

Fig. 2. Preparation of fiber orientation, a) Unilateral and b) Bilateral

A **B**



C **D**

Fig. 3. Composite Products, a) Chopped type, b) Bilateral ($0^o/90^o$), c) Bilateral ($45^o/45^o$), and d) Unilateral (0^o or 90^o)

C. Mechanical Properties

The mechanical and physical properties of the built composites of the natural fiber-reinforced composite material were investigated. These are tensile strength, flexural strength, impact strength, and water absorption. The investigated product of composites was cut as per ASTM standards

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

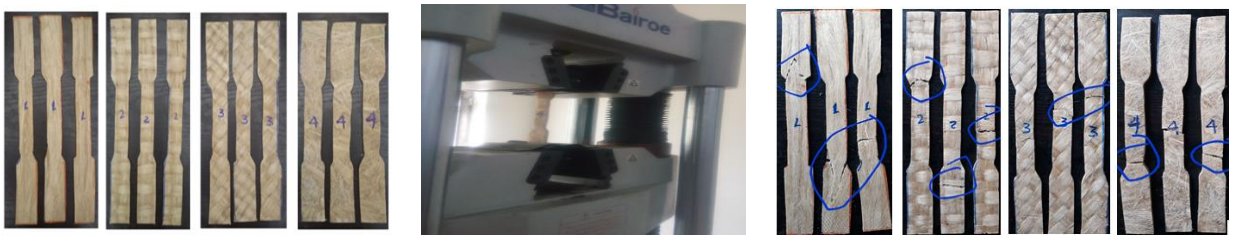
dimension that is D638 for a tensile test, D790 for a flexural test, D256 for an impact test, and D5229M-12 for a water absorption test.

III. Results and Discussion

Manufactured composites of the ʾənäsätə fiber are the reinforcement and the polyester resin forms the matrix, which cross-links the reinforcing fiber and gives its shape with special oriented reinforcement. In addition to this work, the influence of the reinforcing fiber orientation was studied. As shown in experiments, changes in the fiber orientation angle can decrease the strength of the material in specific test directions that significantly improved the mechanical properties of oriented reinforcement composite materials [13].

A. Tensile Strength Analysis

The ultimate tensile strength test analysis is dependent on the fiber orientation as shown in Fig. 4 set up of the Universal Material Testing Machine. The 0^{o}-oriented sample is the highest ultimate tensile strength. It scored 181.41MPa because fibers are oriented parallel to the direction of applied force as shown in Fig. 6b. Concerning fiber orientations, tensile strength will be greatest in the loading direction [14],[15]. Not all specimens broke in the middle section as shown in the failure mode of the specimen. Because the experiments were performed, a significant difference was shown between specimens with the same build parameters. However, in the same building parameter of the specimen, no significant difference was performed [16].



A **B** **C**

Fig. 4. Tensile test, A) specimen, B) Universal Material Testing Machine (Bairoe, Model No. HUT-2000) (Federal Technical and Vocational Education Training Institute lab, Addis Ababa, Ethiopia), and C) The failure mode of the tensile-tested specimen (ware 1, 90 deg.; 2, 0/90 deg.; 3, 45 deg.; 4, Copped fiber)

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

B. Flexural Strength Analysis

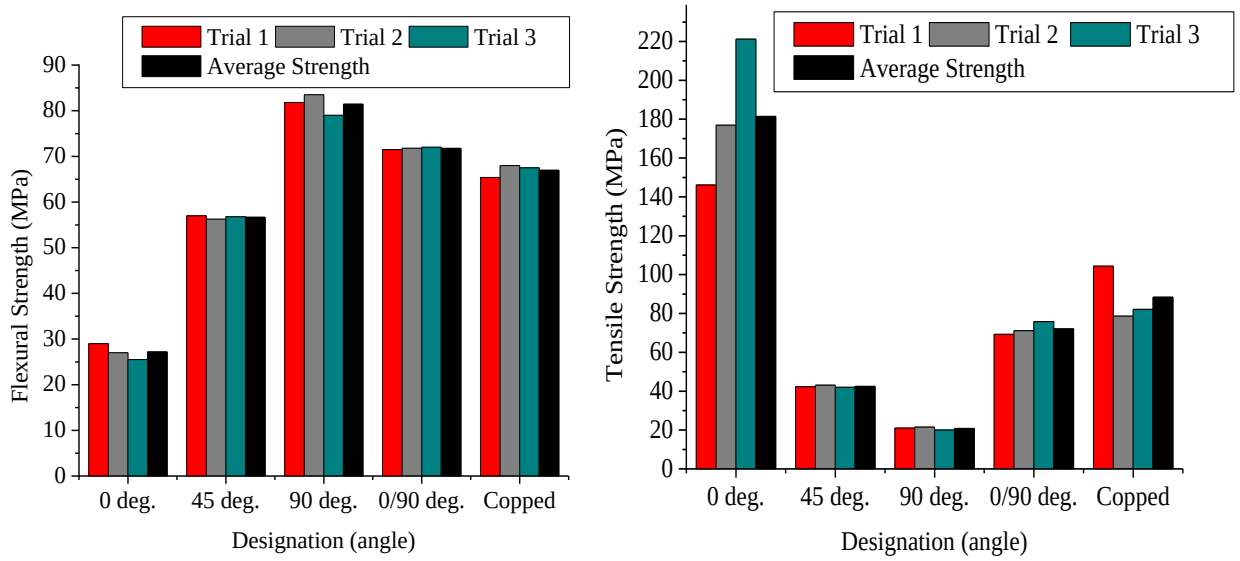
A flexural strength property test was carried out in terms of the force-deflection relationship using the standard method of testing ASTM D790 [17]. Universal Testing Machine (hydraulic universal Amsler testing machine) as shown in Fig. 5 performed the test. The results have recorded the force and deflection in the table with a constant speed of 0.6 mm/min at room temperature by applying a maximum load cell of 25kN. Flexural strength was increased due to the perpendicularity of the fibers loading with a force direction increase as shown in Fig. 6a; the 90^{o} specimen of loading fiber composite was observed with the highest value of 81.43 MPa. The perpendicular direction of loading with the fiber orientation was the higher flexural strength compared to the other [18]. Therefore, when the angle of the fiber loading direction was decreased, the flexural strength also decreased. Chopped fiber is made of a maximum 50mm length randomly and yet evenly distributed strand. It is an easier manufacturing process relative to the other. In addition, good strength was observed. Especially, it is very important for preventing surface cracking because it is a control of three-dimensional force [19]. The failure mode of flexural-tested specimens was observed almost at the center, but some samples were not like that because the thickness and fiber distribution was not exactly the same overall surface. The thickness of the entire area varies by ±0.25mm.

a **b** **c**

Fig. 5. Flexural test, a) Specimen, b) Universal testing machines (hydraulic universal Amsler testing machine) Ethiopian environment and forest research institute lab, Addis Ababa, Ethiopia, and c) The failure mode of flexural-tested specimen

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023



a b

Fig. 6. Strength analyses a) Flexural, b) Tensile strength

C. Impact Strength Analysis

The Izod impact test is used to determine and compare a material of hardness or toughness. V-notches are used on Izod specimens (Fig. 7) to prevent deformation due to energy. In this work, the capacity of a machine is performed at 30J (model; EKE MAT 20) impact on the specimen. The orientation of fibers is the perpendicular direction from a direction of impact force on the specimen having the highest value [20]. Therefore, the sample 90^o oriented fiber scored the highest value which is 9.75 joules. The 45^o/45^o and chopped fiber orientation conducted a high energy absorption capacity than the 0^o/90^o orientation as shown in Fig. 8.

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10

a **b** **c** **d** **E**

Fig. 1. Impact testing specimen, a) 90^0 with force direction, b) 0^0 with force direction, c) $0^o/9^o$ fiber orientation, d) $45^o/45^o$ fiber orientation, and e) chopped fiber

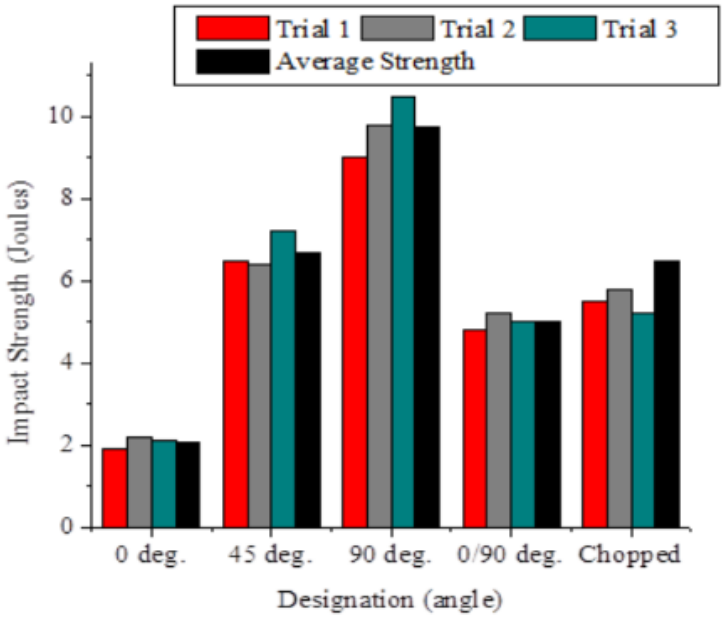


Fig. 8. Impact strength tested analysis

D. Water Absorption Analysis

The samples were soaked in purified water for 120 hours to study water absorption behavior. The water absorption test is used to measure material quality and strength [21]. The 45^o oriented fiber's mechanical strength is found to be lower. As shown in Fig. 8, the highest percentage of water absorption was by the 45^o oriented overlapped fiber portion, which is 15.67% within formed porous portion in the middle part of overlapping fiber and rest portion fiber is not getting wet easily [22]. Water absorption for ʾənäsätə fiber with unsaturation polyester resin composite was

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

constant after 72 hours. Wood plastic composites absorb more water as a result of hydrophilic content factors [23].

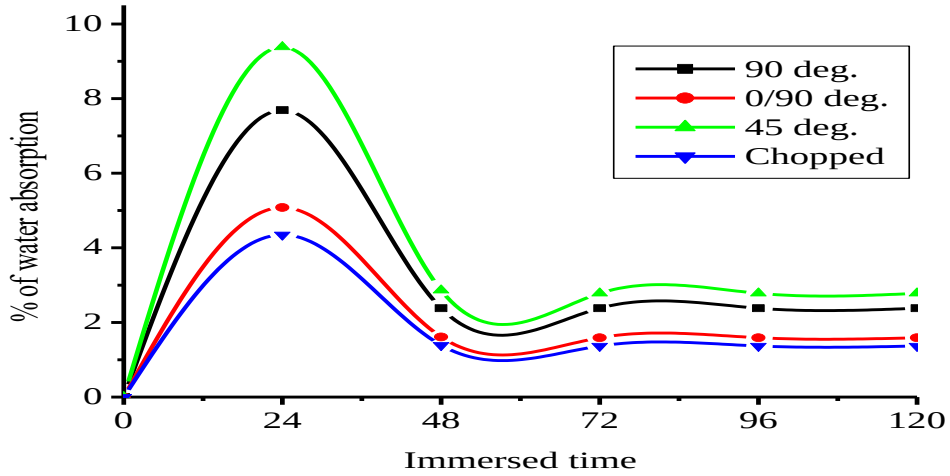


Fig. 9. Rate of water absorption

IV. Conclusion

Samples have been successfully produced by the Hand Lay-up method. The study showed that although the amount of fiber in the composite is the same, they have different mechanical properties due to different fiber orientations. The studied mechanical properties are tensile strength, flexural strength, impact strength, and water absorption rate. Therefore, as the degree of fiber orientation increased from the direction of applied force, the mechanical properties of a composite decreased. The highest value of tensile strength was 0^o oriented fiber which scored 181.41MPa because of fibers oriented parallel to the direction of applied force. The highest value of the flexural strength specimen of 90^o oriented fiber loading composite was observed at 81.43 MPa. The chopped fiber was an easier manufacturing process relative to the other. In addition, good strength was observed. Especially, it is very important for preventing surface cracking because it is a control of three-dimensional force. The impact strength value of the V-notch set-up in a perpendicular direction is higher than that in the longitudinal direction of the fiber. The sample of the 90^0-oriented fiber performed at the highest value of 9.75 joules. The $45^0/45^0$ and chopped fiber orientations conducted a high energy absorption capacity than the $0^0/90^0$ orientations. The water absorption analysis was performed in distilled water until the saturation phase for 120 hours. The highest percentage of water was absorbed in the sample of $45^0/45^0$ oriented fiber.

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

References

[1]. Verma, D., P. C. Gope, X. Zhang, S. Jain, and R. Dabral., "Green composites and their properties: a brief introduction," *In Green Approaches to Biocomposite Materials Science and Engineering* pp. 148-164. IGI Global. DOI: 10.4018/978-1-5225-0424-5.ch007, 2016.

[2]. Rangappa, S. M., and S. Siengchin, "Lightweight natural fiber composites." *Journal of Applied Agricultural Science and Technology*, 3(2): 178-178., 2019. doi.org/10.32530/jaast.v3i2.108

[3]. Motaleb, A. K. Z. M., "Improvement of mechanical properties by alkali treatment on pineapple and jute fabric reinforced polyester resin composites." *International Journal of Composite Materials*, 8(2): 32-37, 2018. DOI: 10.5923/j.cmaterials.20180802.02

[4]. Susilowati, D. S. S. E., and D. Sumardiyanto, "Assessing mechanical properties of pineapple leaf fibre (plf) reinforced composites for automotive applications," *International Journal of Composite Materials,* 8(3): 57-63, 2018.doi:10.5923/j.cmaterials.20180803.02

[5]. Ondiek, W. O., H. T. Ngetha, J. N. Keraita, and J. B. Byiringiro, "Investigating the effect of fiber concentration and fiber size on mechanical properties of rice husk fiber reinforced polyester composites," *International Journal of Composite Materials*, 8(5): 105-115, 2018. doi:10.5923/j.cmaterials.20180805.01

[6]. Pokhrel, S., et al, "Eco-friendly urea-formaldehyde composites based on corn husk cellulose fiber," *International Journal of Composite Materials*, 10(2): 29-36, 2020. doi 10.5923/j.cmaterials.20201002.01.

[7]. Ridzuan, M.n, et al, "The effects of the alkaline treatment's soaking exposure on the tensile strength of Napier fibre." *2nd International Materials, Industrial, and Manufacturing Engineering Conference*, MIMEC2015, Procedia Manufacturing, *2*, 353-358, 2015. doi.org/10.1016/j.promfg.2015.07.062

[8]. Pickering, K. L., M. G. A. Efendy, and T. M. Le, "A review of recent developments in natural fiber composites and their mechanical performance," Composites Part A:

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

Applied Science and Manufacturing, 83, 98-112, 2016. doi.org/10.1016/j.compositesa.2015.08.038

[9]. Getu Temesgen, Alhayat, and Omprakash Sahu, "Process ability enhancement of false banana fiber for rural development," *Cellulose*, 67(67.89): 67-63,2014.

[10]. Davallo, M., H. Pasdar, and M. Mohseni, "Mechanical properties of unsaturated polyester resin," *International Journal of ChemTech Research*, 2(4): 2113-2117, 2010.

[11]. Sari, N. H., I. N. G. Wardana, Y. S. Irawan, and E. Siswanto. "The effect of sodium hydroxide on chemical and mechanical properties of corn husk fiber," *Oriental Journal of Chemistry*, 33(6): 3037-3042, 2017. DOI: http://dx.doi.org/10.13005/ojc/330642

[12]. Kashani, A., T.D. Ngo, P. Hemachandra, and A. Hajimohammadi, "Effects of surface treatments of recycled tyre crumb on cement-rubber bonding in concrete composite foam," *Constr. Build. Mater*, 171: 467–473, 2018.

[13]. Adekomaya, O., and K. Adama, "Glass-fibre reinforced composites: the effect of fiber loading and orientation on tensile and impact strength," *Nigerian Journal of Technology*, (36)3: 782-787, 2017.

[14]. Madhuri, K. H. Sudha, Rao Raghavender, and B. Chandra Mohan Reddy, "Effect of fiber orientation and loading on the tensile properties of Hardwickia Binata fiber reinforced epoxy composites," *Int J Pure Appl Math* 117: 57-61, 2017.

[15]. Kumaresan, M., S. Sathish, and N. Karthi. "Effect of fiber orientation on mechanical properties of sisal fiber reinforced epoxy composites," *Journal of Applied Science and Engineering*, (18) 3: 289-294, 2015.

[16]. Vidakis, N., A. Vairis, M. Petousis, K. Savvakis, and J. Kechagias. "Fused deposition modelling parts tensile strength characterisation," *Academic Journal of Manufacturing Engineering*, 14(2): 87-94, 2016.

[17]. Mayers, F. A., "Paper no.1-d presented at 37th annual conference SPI," *Washington, DC, January*: 11-15, 1982.

[18]. Vinod, B., and L. J. Sudev. "Effect of fiber orientation on the flexural properties of PALF reinforced bisphenol composites," *International Journal of Science and Engineering Applications*, (2)7, 166-169, 2013.

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

[19]. Wallenberger, F.T., J. C. Watson, and H. Li, "*Glass fibers: ASM handbook* 21,"Composite (06781G), 27–34,2001.

[20]. Lasikun, D. Ariawan, E. Surojo, and J. Triyono. 2018. "Effect of fiber orientation on tensile and impact properties of Zalacca Midrib fiber-HDPE composites by compression molding," In AIP Conference Proceedings 1931(1), *AIP Publishing LLC*, 2018. doi.org/10.1063/1.5024119

[21]. Kim, Hyo Jin, "Effect of water absorption fatigue on mechanical properties of sisal textile-reinforced composites," *International Journal of Fatigue,* (28)10: 1307-1314, 2006.

[22]. Karmaker, A. C., "Effect of water absorption on dimensional stability and impact energy of jute fiber reinforced polypropylene," *Journal of materials science letters,* (16)6: 462-464, 1997.

[23]. Ab Ghani, M. H., and S. Ahmad, "The comparison of water absorption analysis between counterrotating and corotating twin-screw extruders with different antioxidants content in wood plastic composites," *Advances in Materials Science and Engineering,* 2011. doi.org/10.1155/2011/406284

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC11

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

EFFECTIVE UTILIZATION OF OMO-KURAZ SUGAR FACTORY BAGASSE ASH AS A SUSTAINABLE PARTIAL REPLACEMENT OF CEMENT IN CONCRETE FOR THE ETHIOPIAN CONSTRUCTIONS

Binaya Patnaik *[1], Jifara Chimdi[2], Seshadri Sekhar T[3]

[1] *Dept. of Civil Engineering, Gambella University. Gambella, Ethiopia*

[2] *Dept. of COTM, Ambo University. Ambo, Ethiopia*

[3] *NICMAR-CISC., Hyderabad, India*

*Corresponding author: binaya7708@gmail.com

Abstract

This paper presents the recycling of sugar cane bagasse ash from the Omo-Kuraz sugar factory in Ethiopia as a cement replacement in concrete that offers a suitable solution to environmental issues related to waste disposal management and the emission of greenhouse gases. The influence of bagasse ash as a cementing material in concrete was examined by performing several strength and durability experiments. From a strength perspective, compressive and splitting tensile strength were tested. As part of durability properties, carbonation and chloride penetrability of bagasse ash concrete was studied. Bagasse ash-based concrete mixes were produced with different cement replacements (10% - 40%) and were tested at different curing periods. As per the strength and durability test results, bagasse ash can be utilized as a cementing material in concrete with 10% cement replacement as the optimum quantity. The durability test results revealed bagasse ash doesn't have adverse effects from carbonation and chloride penetrability perspective on concrete. This indicates that the Ethiopian construction industry can consider bagasse ash as non-conventional cementing material.

Keywords: ***Bagasse ash, Compressive strength, Sorptivity, Tensile strength, Workability***

***Received**: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published:** 30 April 2023.*
*Corresponding author- **Binaya Patnaik***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC11

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

I. Introduction

Sugarcane is one of the main crops grown in about 110 countries with an estimated total production of over 1500 million tons. From an Ethiopian perspective, according to Ethiopian Sugar Corporation data, currently, there are about eight operational sugar factories namely Wonji Shoa, Metehara, Finchaa, Tendaho, Arjo-Dedesa, Kessem, Omo-Kuraz II and Omo-Kuraz III which are producing 3.5 to 4 million quintals of sugar annually. Other five sugar factories are under different levels of construction at Omo-Kuraz (Omo-Kuraz I and IV), Tana Beles (Tana Beles I and II) and Welkayte Sugar Development Projects. When expansion and new sugar development projects are completed, Ethiopia will have 13 sugar factories with a potential of 2.25 million tons of sugar yearly. As a result, sugarcane plantations are expanding with current area coverage of over 102 thousand hectares [1].

Sugarcane bagasse ash (SCBA) is a by-product of sugar production factories. After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue is obtained, which is reused in the same industry as fuel in boilers for heat generation leaving behind 8 -10 % ash as waste, known as sugarcane bagasse ash (SCBA) [2]. Currently in Ethiopia, the total crushing capacity of sugarcane in eight factories is about 74,350 tons per day which yields about 2,677 tons per day of SCBA or 977,105 tons per year. The expected SCBA obtained from 13 factories is 1.97 million tons annually after the extension and the completion of new projects.

The SCBA contains high amounts of silicon, un-burnt matter, calcium oxides and aluminum. The ashes produced directly from the mills are not reactive as these are not burnt under controlled conditions. The ash, therefore, becomes industrial waste and poses disposal concerns. A few studies have been carried out in the past on the utilization of bagasse ash obtained directly from the industries to study pozzolanic reactivity and their aptness as binders by partially replacing fine aggregate [3], [4]. It has been found that under a controlled burning below 700° C incinerating temperature for about 1 hour it converts the silica content of ash into amorphous silica. The reactivity of this amorphous silica is directly proportional to the specific surface of the ash. The SCBA formed after the controlled burning condition is ground or pulverized to the required fineness before mixing with the blended concrete.

***Received**: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published:** 30 April 2023.*
*Corresponding author- **Binaya Patnaik***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC11

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

The present experimental investigation was carried out to study the use of SCBA as a partial replacement of cement in concrete. This would help in resolving the issues related to the disposal of SCBA and reduce the greenhouse gases emitted due to the use of cement in concrete which possess a serious threat to our environment and ecology. The experimental study examines the workability properties of fresh concrete such as slump and compressive strength and tensile strength of concrete at 7, 28 and 90 days with 0%, 10%, 20%, 30% and 40% replacement of fine aggregate with bagasse ash by weight.

II. Materials And Methods

Materials

Ordinary Portland Cement (OPC) of 42.5 grade and SCBA from Omo-Kuraz II sugar factory, Ethiopia, were used for this study. The SCBA obtained from the factory was further burnt at 650° C for an hour to bring down the carbon content and further ground to pass through a 90 µm sieve. A sample of SCBA from the Omo-Kuraz II sugar factory is shown in Fig. 1. The physical and chemical properties of cement and SCBA are presented in table 1 and table 2.

Table I: Physical Properties of Cement and SCBA

Material	Density	Specific gravity	Fineness (µm)	Specific surface (m^2/kg)	Mean grain size
OPC	1.15	3.15	82	300	21
SCBA	0.42	1.71	90	890	5.2

Table 2: Chemical Properties of Cement and SCBA

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	LOI
OPC	21.55	5.69	3.39	64.25	0.85	0.33	0.59	2.47	1.80
SCBA	87.40	3.60	4.90	2.56	0.69	0.15	0.47	0.11	8.25

Locally available angular crushed granite metal having a maximum size of 20 mm was used as coarse aggregate having a fineness modulus of 7.63 and sp.gr of 2.65, bulk density of 1468 kg/m^3 at the compacted state and water absorption of 1.2% respectively. River sand with a specific gravity of 2.5, fineness modulus of 2.8, bulk density of 1700 kg/m^3 at the compacted state and

Received: *14 February 2022;* ***Revised:*** *17 March 2023;* ***Accepted***: *20 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Binaya Patnaik***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC11
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

water absorption of 2.04% respectively were used as fine aggregate. Clean and impurities-free (acids, alkalis and oils, etc.) Potable water was used for mixing concrete and curing.

Fig 1. SCBA from Omo-Kuraz II sugar factory

As per the code book ACI 211, the mix design was carried out and several materials were designed. To find the optimum percentage of SCBA in concrete as a partial replacement of cement, five types of mixes (BA0, BA10, BA20, BA30 and BA40) were arranged by partially replacing cement with SCBA from 0% to 40%. Concrete test specimens of the above-mentioned mixes of size 150mmx150mmx150mm were cast and tested for their compressive and tensile strength at 7, 28, and 90 days. The mix proportions have been presented in table 3.

Table 3: Mix Design and Proportion of C35 Grade Concrete

Grade	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate kg/m^3)	W/C ratio	Water (kg/m^3)	Mix proportion
C-35	452	793	910	0.42	190	1:1.754:2.013

B. Experimental Procedure

For the preparation of good concrete, the vital factors are appropriate mixing, compaction, and sufficient curing which were adopted during the test sample preparation process. A pan mixture was used for the mixing process and the time for mixing was kept for 3-4 minutes. To examine the workability properties of a fresh concrete slump, the test was performed. 24 hours after casting, the test samples were de-molded and adequately cured using potable water. The test specimens were tested for their compressive strength and tensile strength at three different ages i.e., 7 days, 28 days, and 90 days by using cube samples of size 150 mm x150mmx150mm. The rapid chloride permeability test (RCPT) was conducted using concrete discs of size 100 mm dia. x 50 mm ht.

Received: *14 February 2022;* ***Revised:*** *17 March 2023;* ***Accepted***: *20 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Binaya Patnaik***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC11
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

Each test result was averaged out from three test specimen test results. The sample of fresh concrete and test sample casting is shown in Fig. 2 and Fig.3 respectively.

Fig 2. Fresh Concert

Fig 3. Preparation of test sample

III. Results and Discussions

A. Effects of SCBA on Fresh Properties of Concrete

The effect of the replacement of cement by bagasse ash partially from 0% to 40% on the workability of concrete is shown in table 4.

Table 4: Slump values of different Concrete Mixes

Sr. No.	Proportions of SCBA	Concrete slump (mm), to nearest 5mm
1	0%	45
2	10%	40
3	20%	40
4	30%	35
5	40%	28

It can be observed from table 4 that there is no considerable loss of workability by replacing SCBA with cement by up to 20%. Increased water requirement has been described previously [5] when SCBA replaces cement, which is mostly due to the porous nature of the fine particles, high surface area and the un-burnt carbon content. Furthermore, the irregular shapes and angularity of the SCBA also increase the water requirement by providing particle catch points that need extra water to permit them to unlock hydraulically.

Received: *14 February 2022;* ***Revised:*** *17 March 2023;* ***Accepted***: *20 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Binaya Patnaik***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC11
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

B. Effects of SCBA on Compressive Strength of Concrete

The effect of the replacement of cement by SCBA partially from 0% to 40% on compressive strength (in MPa) of concrete at different ages is shown in table 5.

Table 5: Effect of SCBA on Compressive Strength of Concrete

Mix	% SCBA replacement	Density (kg/m^3)	Compressive strength at different age		
			7 days	28 days	90 days
C35	0%	2359	25.30	40.78	46.2
	10%	2360	26.90	45.66	48.7
	20%	2351	20.32	35.57	38.22
	30%	2461	18.65	20.63	32.62
	40%	2335	8.78	11.62	16.22

It can be clearly seen from table 5 that the compressive strength of concrete is rising from normal concrete (0% replacement) to concrete with 10% of SCBA as partial replacement of cement. By further rising the SCBA content as a replacement for cement the compressive strength is reducing. A similar tendency of strength difference can be observed at different ages of testing i.e., 7 days, 28 days, and 90 days. It can also be seen that, with an increase in the age from 7 days to 28, and 90 days, the compressive strength increases for all types of mixes which are especially due to the delayed pozzolanic effect of SCBA in concrete. The causes for compressive strength development in SCBA blended concretes and the rise in compressive strength for up to 10% cement replacement of SCBA may be due to the high silica content, amorphous phase, fineness, degree of reactivity of SCBA, specific surface area and pozzolanic reaction between reactive silica in SCBA and calcium hydroxide in an alkaline environment. Based on the above test results, it has been established that 10% of SCBA from the Omo-Kuraz sugar factory is optimum to be used as a partial replacement of cement in the manufacturing of concrete from a compressive strength perspective.

C. Effects of SCBA on Tensile Strength of Concrete

The effect of the replacement of cement by SCBA partially from 0% to 40% on tensile strength (in MPa) of concrete at different ages is shown in table 6.

Received: *14 February 2022;* ***Revised:*** *17 March 2023;* ***Accepted***: *20 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Binaya Patnaik***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC11

Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

Table 6: Effect of DCBA on Tensile Strength of Concrete

Mix	% SCBA replacement	Density (kg/m^3)	Tensile strength at different age		
			7 days	28 days	90 days
C35	0%	2359	2.89	3.36	3.54
	10%	2360	2.90	3.81	4.11
	20%	2351	1.70	2.38	2.68
	30%	2461	1.49	2.09	2.21
	40%	2335	1.45	1.58	1.84

It can be clearly seen from table 6 that the tensile strength of concrete is rising from normal concrete (0% replacement) to concrete with 10% of SCBA as partial replacement of cement. By further rising the SCBA content as a replacement for cement the tensile strength is reduced. A similar tendency of strength difference can be observed at different ages of testing i.e., 7 days, 28 days, and 90 days. It can also be seen that, with an increase in the age from 7 days to 28 and 90 days, the tensile strength increases for all types of mixes which are especially due to the delayed pozzolanic effect of SCBA in concrete.

Based on the above test results, it has been established that 10% of SCBA from the Omo-Kuraz sugar factory is optimum to be used as a partial replacement of cement in the manufacturing of concrete from a tensile strength perspective.

D. Relationship between Compressive and Tensile Strength of SCBA Concrete

Mathematical equations have been derived to express split tensile strength and compressive strength of concrete (in MPa) with different percentages of bagasse ash. Fig 4. shows the relationship between split tensile strength and compressive strength at 28 days. The equation obtained is as shown below:

For 0 up to 40% replacement of bagasse ash,

TS = 0.056* CS + 0.8175 and 'R^2'= 0.8935

Where, TS = Tensile Strength, CS = Compressive Strength, R^2 = Correlation Coefficient

Received: *14 February 2022;* ***Revised:*** *17 March 2023;* ***Accepted***: *20 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Binaya Patnaik***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC11

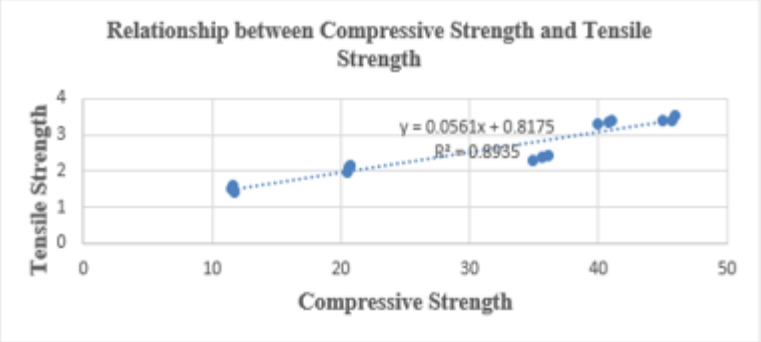


Fig. 4. Relationship between Compressive Strength and Split Tensile Strength

E. Effects of SCBA on Chloride Permeability of Concrete

The effect of the replacement of cement by SCBA partially from 0% to 40% on charge passed by Columbus and chloride permeability of concrete at 28 days curing period is shown in table 7.

Table 7: Chloride Penetration in Concrete Mixes

Type of mix	Charge passed in coulombs	Chloride ion penetrability as per ASTM C1202
RCPT-0	2637.77	Moderate
RCPT-10	1885.61	Low
RCPT-20	1384.64	Low
RCPT-30	2121.05	Moderate
RCPT-40	2823.25	Moderate

From table 7, it can be observed that with partial replacement of cement with bagasse ash of up to 20%, the permeability of concrete is decreasing compared to the controlled concrete. However, beyond 20% of cement replacement with bagasse ash, the permeability of concrete is increasing as compared to the controlled concrete. The decrease in the charge passed with the increase in bagasse ash is mainly because of the pozzolanic effect of bagasse ash that makes the concrete impervious by consuming the calcium hydroxide, which is the main cause of making concrete previously, produced from the hydration of cement. The level of chloride ion penetration for concrete with bagasse ash of 10% and 20% as partial replacement of cement remains in the “Low” range as per ASTM C1202 [5] and thus demonstrates that these have a good ability to resist

Received: *14 February 2022;* ***Revised:*** *17 March 2023;* ***Accepted***: *20 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Binaya Patnaik***

chloride ion penetration. It is also expected that with the increase in age when most of the hydration of concrete with bagasse completes, the chloride permeability of concrete will decrease drastically.

F. Effects of SCBA on Carbonation of Concrete

The carbonation test was conducted for various mixes and no carbonation depth was seen for any of the mixes. This indicates that these mixes are not affected by the local environmental conditions. Fig. 5. Shows the concrete cylinders subjected to carbonation test.

Fig. 5. Concrete Cylinders Subject to Carbonation Test

IV. Conclusions and Recommendations

Based on the present experimental investigation carried out, the following conclusions have been made.

- The use of SCBA as a partial replacement of cement in concrete helps in addressing the dumping-related issues of sugar factories and reduces environmental impacts.
- The optimum percentage of SCBA in concrete as a partial replacement of cement in concrete from a strength perspective is found to be 10%.
- Water demand for SCBA blended concrete increases with an increase in the SCBA content.
- With the inclusion of bagasse ash as a cementing material in concrete by up to 20%, the permeability of concrete is decreasing compared to the controlled concrete.
- There is no effect of carbonation in SCBA-based concrete.

Received: *14 February 2022;* ***Revised:*** *17 March 2023;* ***Accepted***: *20 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Binaya Patnaik***

References

[1]. Ethiopian Sugar Corporation. Sugar Industry in Ethiopia. Addis Ababa: ESC, 2019.

[2]. J. Paya et al., "Sugarcane bagasse ash (SCBA): Studies on its properties for reusing in concrete production," *Journal of Chemical Technology & Biotechnology*. vol. 77, no.3, pp. 321–325, Mar. 2002.

[3]. E. C. Mansaneiraet al., "Sugar cane bagasse ash as a pozzolanic material," *DYNA*. vol 84, no.201, pp. 163-171, June 2017.

[4]. S.Sundararamam and S. Azhagarsamy, "Experimental study on partial replacement of cement by bagasse ash and M-Sand in concrete," *International Journal of Advanced Technology in Civil Engineering*, vol. 2, no.2, pp. 150-152, Apr. 2013.

[5]. N. Chusilp, C. Jaturapitakkul, and K. Kiattikomol, "Utilization of bagasse ash as a pozzolanic material in concrete," *Construction and Building Materials*, vol. 23, no. 11, pp. 3352–3358, Nov. 2009.

[6]. *Rapid Chloride Permeability (Columbus Passed),* ASTM C1202, Dec. 2002.

***Received**: 14 February 2022; **Revised:** 17 March 2023; **Accepted**: 20 March 2023; **Published:** 30 April 2023.*
*Corresponding author- **Binaya Patnaik***

ETHIOPIAN INTERNATIONAL JOURNAL OF ENGINEERING AND TECHNOLOGY

About EIJET

The Ethiopian International Journal of Engineering and Technology (EIJET) is a non-profit peer-reviewed open-access academic research Journal of Arba Minch Institute of Technology under Arba Minch University, Ethiopia. The scope of the Journal covers multidisciplinary and cross-disciplinary areas of study in engineering and technology. The peer-reviewed International Journal publishes all types of quality research papers, case studies, review papers, experimental and empirical papers, and shortened thesis/ dissertations in the broad area of engineering and technology.

The Journal is specifically dedicated to publish novel research contributions and innovative research outcomes in the following fields of engineering and technology: -

- *Intelligent Computing and Information Technology,*
- *Mechanical and Metallurgy Engineering,*
- *Architectural Design and Town Planning,*
- *Civil and Transport Engineering Systems,*
- *Electrical Engineering and Power Electronics,*
- *Emerging areas of Renewable Energy*
- *Papers related to allied disciplines, emerging technologies, and future-generation engineering paradigms will be given priority for publication.*

The Journal publishes papers from worldwide sources, especially for covering the emerging issues of engineering and technology from developing and developed countries. The Papers from African continent countries having localized problem-solving research will be given priority.

Arba Minch University
Arba Minch Institute of Technology
Arba Minch, Ethiopia
Phone: +251 46 881 4970
Fax: +251 46 881 4971