JOURNAL OF ADVANCED INDUSTRIAL TECHNOLOGY AND APPLICATION
e-ISSN: 2716-7097

JAITA

Vol. 6 No. 1 (2025) 93-100
https://publisher.uthm.edu.my/ojs/index.php/jaita

Replacement of Sisal Fiber with Jute Fiber in the Production of Plaster of Paris (POP) Ceiling Boards

Usiju. S. Francis[1], Mohammad B. Yawale[1]*, Abdulhameed U. Abubakar[1], Ismail A. Yahya[1], Yazid Aliyu[1], Murtala M. Hassan[2], Mamman Hamadu[1]

[1] *Structural & Geo – Environmental Research Group, Department of Civil Engineering, Modibbo Adama University, 2076 Yola – Adamawa State, NIGERIA*

[2] *Geotechnical Engineering Research Group, Modibbo Adama University, 2076 Yola – Adamawa State, NIGERIA*

*Corresponding Author: mohammadybuba@mau.edu.ng
DOI: https://doi.org/10.30880/jaita.2025.06.01.008

Article Info

Received: 22 December 2024
Accepted: 26 April 2025
Available online: 30 June 2025

Keywords

Plaster of Paris, ceiling, jute fiber, sisal fiber, flexural strength, nail pull resistance

Abstract

Plaster of Paris (POP) ceiling boards production is reported to be too expensive, this hinder affordability especially to low-income earners in Nigeria. It high cost is attributed to importation of its constituent materials (Gypsum cement and Sisal fiber). This study assessed the performance of jute fiber as compare to sisal fiber in POP ceiling production. Sisal fiber is imported and sold at exorbitant price within the country. The materials used in this study includes gypsum cement, sisal and jute fibers. The jute fiber was obtained from jute stalks bought from Girei market in Girei LGA Adamawa State, Nigeria. These stalks were retted using tank retting method, and fibers obtained were chemically modified. Specimens were prepared and tested using standard methods outlined in ASTM C 473 – 07 (2009). Flexural strength, nail pull resistance and water absorption of the specimens were determined. Use of jute fiber as reinforcement in POP ceiling boards was found to enhance flexural strength and nail-pull resistance by 4% and 3% respectively. The water absorption of sisal and jute fibers specimens are 6% and 7% which are all within ASTM C1396M-11 (2004) specified maximum limit. Hence jute fiber is considered a suitable alternative to sisal fiber in POP ceiling production Nigeria.

1. Introduction

Secondary or architectural elements in structures are components which although add to building design dead loads, but do not take part in the resistance against design actions. These elements are essential for buildings to be complete and function satisfactorily [1]. While the strength and stiffness to the building is provided by the structural elements, non-structural elements are required to provide insulation against heat/sound, protection from climatic elements such as rain or sun and compartmentalization which are very important in making the building habitable. Some of these elements in residential and commercial buildings are roofs, ceilings, partitions, windows etc.

The failure of suspended ceiling systems is one of the most frequently reported type of nonstructural damage in buildings especially during natural hazards such as wind or earthquake [2]. Ceilings failure results in costly repairs and replacements which is also time consuming. Services and engineering systems damage within the plenum space of the ceiling can be critical and affect the performance and serviceability of buildings negatively. According to [3], identifying the damage states and performance issues in suspended ceilings has been the subject of many recent studies. Ceiling is in most cases a horizontal non-structural member which covers the upper part

of a building internal space. However non-structural member, but in most buildings, fittings such as electric lights, smoke detector and security cameras are attached to it. Hence, it must be capable of carrying its self-weight, dust and any other fittings attached to it.

In the previous, ceiling boards were produced from different materials such as waste paper, asbestos and other agricultural residues. Some of these materials have been identified to be hazardous to human health hence proscribed by different governments. For instance, cancer resulting from asbestosis was discovered to be caused by asbestos [4]. To avoid this, search for safer materials for the production of ceiling boards has garnered momentum. One of the most commonly used suspended ceiling in Nigeria today is the Plaster of Paris (POP) ceiling boards, this is due to their aesthetic value and good thermal insulation. For many centuries Plaster of Paris was well known as a building material where Romans as well as Egyptians used it for plastering walls.

POP is a white cementitious powder which when mixed with water set to a hard solid [5]. Plaster of Paris is a brittle material with low mechanical integrity and under tensile stress/mechanical load it develops micro-macro cracks which affect the structural performance and durability of the material. However, these cracks could be minimized by reinforcing it with appropriate material [6]. Various types of reinforcing materials have been discovered and used to improve the structural performance of POP, this includes but not limited to steel, glass, polymers, wood and fibre [7]. Study by [8] has shown that the incorporation of natural fibers with Plaster of Paris changes the mechanical and rheological behavior of the material and significantly increase its cracking threshold and ductility. The mechanical properties of this composite material are also affected by the orientation and arrangement of the fibers. According to [9] Plaster of Paris ceiling is mostly a composite material, that consists of fibre of high strength and elastic modulus bonded or embedded in a matrix with distinct interfaces (boundary), both the matrix and fibre retained their physical and chemical identities hence augmenting the structural deficiency of one another. Fibers are the major load-carrying members and act as crack arresters in this type of ceiling, while the surrounding matrix keeps them in the desired orientation and location [9]. fibers used as reinforcing material in POP ceiling may either be synthetic or natural.

According to [10], POP ceiling is mostly used by elites in Nigeria, this is due to its high cost. Another study by [11] also reported that POP ceiling is not affordable to low-income earners who need a convenient and comfortable building due to its expensive nature. This may be due to the high cost associated with importation of the two major component of this ceiling (i.e gypsum powder and fiber). today in Nigeria, the fibers used as reinforcement in POP ceiling are processed sisal fibers imported from overseas. This contributes to high cost of the ceiling thereby making it unaffordable for developers.

Nigeria is blessed with a lot high fibre yielding plants such as okra, jute, knafe, banana leaves and many others whose fibers could be processed and employed as reinforcement in different composite building material including POP ceiling boards. The use of natural fiber in the production of plaster of Paris (POP) ceiling boards can be considered as low-cost and eco-friendly sustainable engineering practices. Jute and sisal fibers are natural fibers that possess unique mechanical properties, these make them suitable for composite applications, including ceiling boards. A study by [12] has shown that composites with a higher jute fiber proportion exhibited improved stiffness and strength as compared to those dominated by other fibers. This can be attributed to finer diameter of jute, which ensures a greater surface area for bonding within the composite matrix, thereby improving mechanical performance [12]. Jute has a substantial cellulose content, contributing to its thermal properties and mechanical strength, making it a suitable alternative for replacing sisal in composite applications [13].

Environmentally, both sisal and jute fibers are renewable resources which are biodegradable, this aligns with the growing demand for sustainable and eco-friendly building materials but in this part of the world jute fibers is cheaper. The use of synthetic materials will drastically be reduced by adopting the use of natural occurring materials such as jute fibers, thus lowering the carbon footprint associated with construction materials [14]. Furthermore, jute fibers processing requires lesser energy as compared to synthetic fibers, this add to their sustainability profile [15]. It is revealed that jute fibers can effectively enhance flexural and tensile strength of composites. For instance, composites produced with jute fibers have shown favorable results in terms of overall durability and impact resistance, which are crucial factors for ceiling board applications [16].

The comparison of jute and sisal fibers shows that jute fibers provide better mechanical properties when used in specific composite formulations with the fact that sisal fibers have higher cellulose content [13]. Thus, this study intended to investigate the performance of jute fiber as compared to sisal fiber in POP ceiling board production not only to enhances the performance of the composite ceiling board and to align with sustainable practices in material engineering but also to reduce cost.

2. Methods

The Materials used in this research include plaster of paris (POP) cement, water, sisal fiber, jute fiber and Sodium Lauryl Sulfate. The entire process of pop ceiling board production is summarized in Fig. 1.

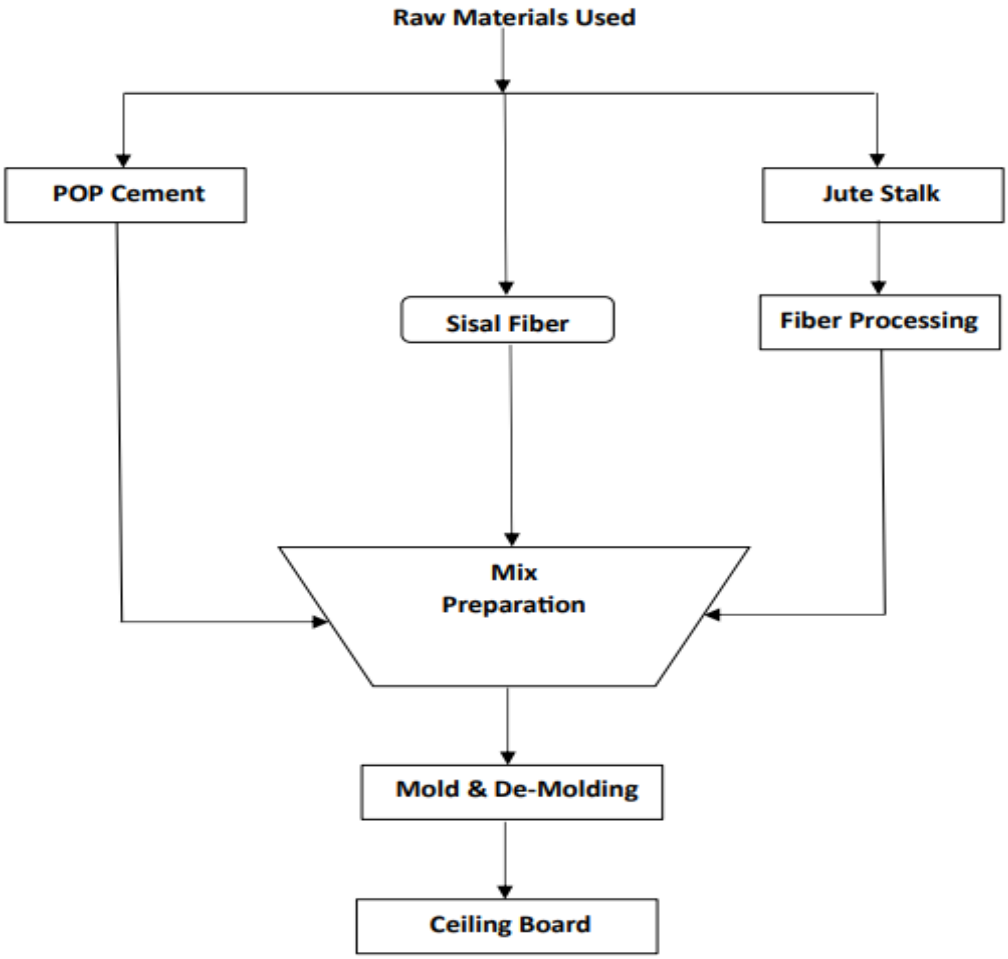


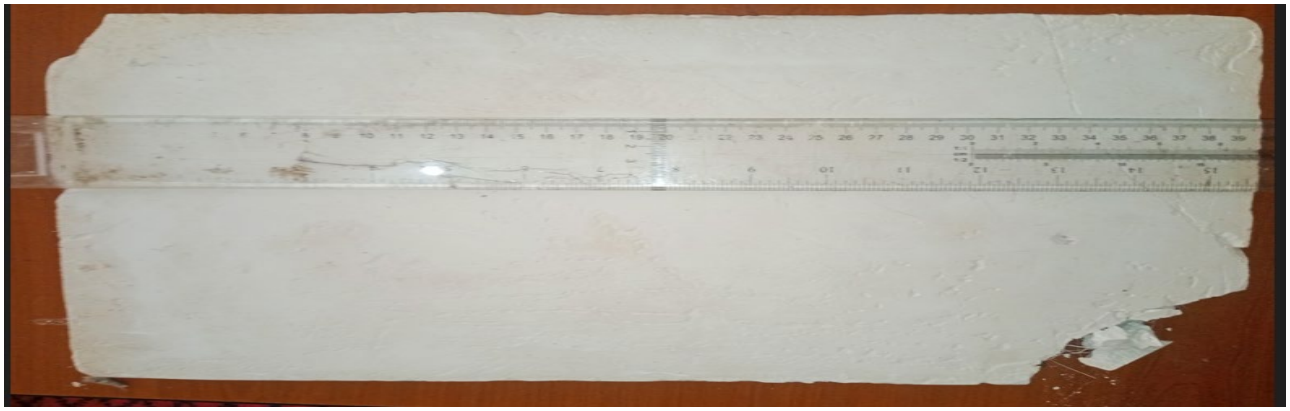
Fig. 1 *Process flow diagram*

The jute stalks were sourced from Girei market in Girei LGA Adamawa State and processed in the department of Civil Engineering, Modibbo Adama University (MAU) Yola. Extraction involved a water retting process, where the plant stalks were fully immersed into water in a steel tank for a period of fourteen (14) days, this allowed microbes to thrive and produced enzymes that help in breaking down of lignin and peptic substances. This is followed by thorough washing to eliminate any remaining organic matter. Subsequently, manual stripping of the fibers into long and short threads was conducted. The fibers obtained were then chemically treated with 10% Sodium Lauryl Sulfate (SLS) for a period of thirty (30) minutes and then dried after washing with distilled water.

POP cement was thoroughly mixed using a water/binder ratio of 0.55 for 3 minutes which formed a consistent paste with no lumps. The paste was poured gently filling half of the mold of 400 x 250 x 12 mm dimensions. Three percent (3%) of fiber was laid in the mold in a randomly orientated manner before being filled with paste matrix, and the materials used per samples is as shown in Table 1. Hardening period was observed for 30 minutes. The samples were smoothen using a straight edged tool as depicted in Fig. 2. After hardening, over a 3days and 7days curing period, the specimens were de-molded and tested. A total of twenty-four specimens were prepared, consisting of twelve panels reinforced with sisal fiber and twelve panels reinforced with jute fiber. In each fiber type, three panels were used for flexural, nail pull resistance and water absorption tests respectively.

Table 1 *Materials used per sample*

S/N	Material	Quantity of Material (g)
1	POP cement	1008
2	5% fiber	50
3	Water	555



(a)

(b)

(c)

Fig 2 *(a) Length Measurement; (b) Width Measurement; (c) Finished POP ceiling board*

A Universal Testing Machine (UTM) from the department of building MAU Yola, was used to conduct flexural test (bend test) on three specimens each from sisal and jute fibers for each curing age, in accordance with flexural strength test (Method A) of [17]. In performing this test, the specimen was placed on the machine with the axis oriented horizontally. Load at a constant rate was applied to the specimen in the middle as shown in Fig. 3. The load that causes the breaking of each specimen was recorded and average computed.

(a)

(b)

Fig. 3 *(a) Specimen before test; (b) Specimen under test*

The nail pull resistance test was conducted on universal testing machine, in accordance with method B of [17]. The specimen was supported on a plate with a 76mm diameter hole in the center and it was positioned to ensure that the surface of the plate is perpendicular to the travel of the test nail. The nail was attached at the head to the

movable head of the test apparatus. Constant rate load was applied and forces required to push the nail head through the specimens as shown in Fig. 4.

(a) **(b)**

Fig. 4 *(a) Specimen under test; (b) Specimen after test*

The water absorption test was carried out by inserting specimens in water at constant room temperature following the procedure outlined in [17]. The results of the test after curing were recorded.

3. Results

The results for flexural strength test of POP ceiling boards reinforced with imported sisal fiber and those reinforced with locally sourced jute fiber are presented in Fig. 5. The results demonstrated that the flexural strengths which is represented as the collapse load of the two fibers progressively increased during curing. The flexural strength for jute fiber and imported sisal fiber are 191N and 188N at 3 days age, and 201N and 197N at 7 days age respectively. The jute fiber reinforced ceiling board (JFRCB) is found not only meeting the minimum flexural strength of 178N specified by [18] but also outperformed the value for sisal fiber reinforced ceiling board (SFRCB) by 4%. Hence, jute fiber exhibited enhance flexural strength when compared to sisal fiber in POP ceiling production as similarly reported by [13] in a different composite formulation.

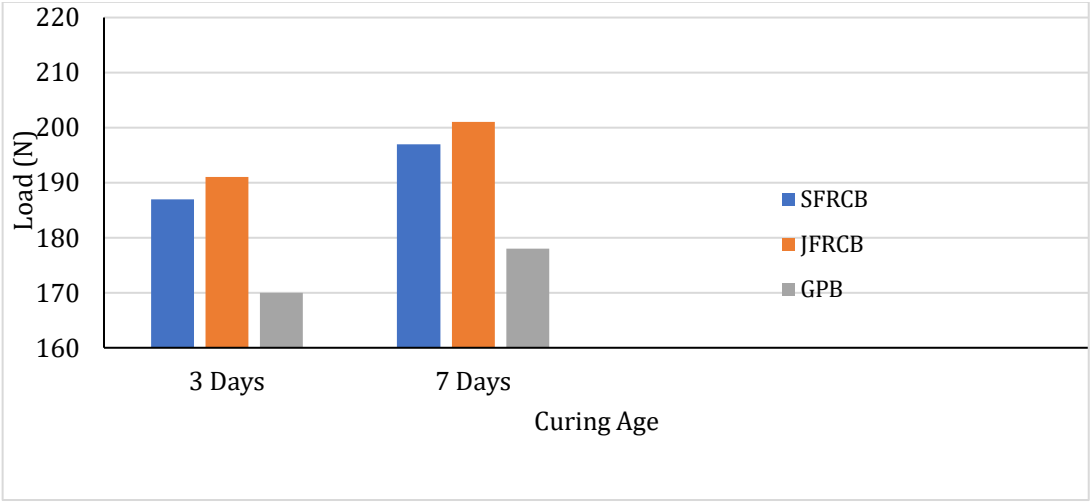


Fig. 5 *Flexural strength of POP ceiling board*

The results of the pull resistance tests are presented in Fig. 6. The average pull resistance of POP ceiling boards reinforced with locally sourced jute fiber and imported sisal fiber are 360N and 351N, respectively. These are higher than the minimum value of 34 N recommended for gypsum panel boards (GPB) by [18].

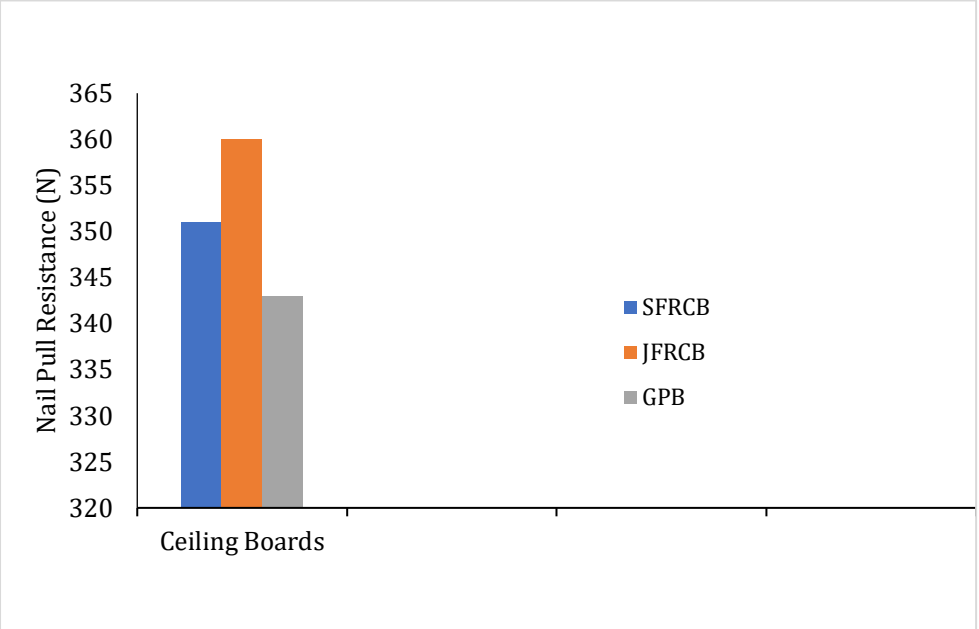


Fig. *6 Nail pull resistance of POP ceiling board*

The water absorption test results indicated that the ceiling boards prepared using locally sourced jute fiber and sisal fiber have a mean water absorption value of 7% and 6% respectively. These values are all within the maximum water absorption limit of 10% specified in [18].

4. Conclusion

4.1 Summary of Research Work

In this research study the performance of Plaster of Paris (POP) ceiling boards reinforced with two different natural fibers was investigated: imported sisal fiber and locally sourced jute fiber. The study evaluated the physical and mechanical properties of these fiber-reinforced ceiling boards and established a better alternative for sustainable solution.

4.2 Executive Summary of the Results

The findings of the study revealed that POP ceiling boards reinforced with jute fiber exhibited superior pull resistance and flexural strength as compared to those reinforced with sisal fiber. However, higher water absorption was observed in jute fiber-based boards than the sisal fiber counterparts, but the water absorption was still within acceptable limits specified by relevant standards. Overall, jute fiber surpassed sisal fiber in all the mechanical tests carried out, making it a better alternative for reinforcement in the production of POP ceiling board. Moreover, the use of jute fiber promises to be more cost efficient and aligns with the growing trend of sustainable material consumption.

4.3 Recommendation/Further Work

Going by the findings, jute fiber is recommended as a viable substitute to sisal fiber for POP ceiling board reinforcement due to its local availability and higher mechanical properties. Further study should concentrate on optimizing the water absorption property of jute fiber-reinforced boards through composite modifications or surface treatment. Furthermore, long-term durability assessments and large-scale production studies should be carried out to evaluate its performance under various environmental conditions. If adopted, the use of jute fiber has the potential of significantly reducing production costs and creating job opportunities for local communities.

Acknowledgement

The authors acknowledge the help of Mr. Joseph Haruna of the Department of Building and the entire lab team of Civil Engineering, all in Modibbo Adama University, Yola. We also thank these departments for providing equipment and facilities used for this study.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***conception and design of the study****:* U. S. Francis**,** *A. U. Abubakar, M. B. Yawale;* ***data collection:*** U. S. Francis**,** *M. Hamadu, Y. Aliyu, M. B. Yawale;* ***analysis and interpretation of results:*** U. S. Francis*, M. B. Yawale, I. A. Yahya, A. U. Abubakar;* ***draft manuscript preparation:*** *M. M. Hassan, I. A. Yahya, Y. Aliyu, A. U. Abubakar, M. B. Yawale. All authors reviewed the results and approved the final version of the manuscript.*

Reference

[1] Rajesh, P. D., Gregory, A. M., Atefeh, P. and Giacomo, P. (2015). Seismic fragility of suspended ceiling systems used in NZ based on component tests. *Bulletin of the New Zealand Society for Earthquake Engineering, Vol. 49, No. 1, March 2016*

[2] Ozgur, O., Ibrahim, S. M., and Serhan S. (2017). Performance evaluation of suspended ceiling systems using shake table test *General Directorate of State Hydraulic Works, Izmir, Turkey*

[3] Badillo-A., H., Whittaker, A. S. and Reinhorn, A. M., (2007). *Seismic* fragility of suspended ceiling systems. *Earthquake Spectra*, 23 (1), pages 21-40. Good practice guide for design, installation and maintenance of building fixtures Building and Construction Authority www.bca.gov.sg

[4] Anowai, S. I., Tok, D. Y., Sunday, A. J. (2020). Comparative study of performance of plaster of paris ceiling boards reinforced with imported sisal fibre and locally sourced okra fibre *International Journal of Modern Trends in Engineering and Research (IJMTER) Volume 07, Issue 06, [June-2020]* ISSN (Online):2349–9745; ISSN (Print):2393-8161

[5] Ezugwu, C. N., Uneke, L. A. and Akpan, P. P. (2015). Rice husk ash-an alternative to gypsum in POP board *International Journal of Engineering, Science and Mathematics*, 4(4), 24-34.

[6] Akubueze, E. U., Ezeanyanaso C. S., Orekoya E. O., Akinboade D. A., Oni F., Muniru S. O. and Igwe C. C. (2014). 'Kenaf Fibre (Hibiscus cannabinus L.): A viable alternative to jute fibre (Corchorus genus) for Agro-Sack Production in Nigeria' *World Journal of Agricultural Sciences. 2014;10(6).*

[7] Mohammed, I. Y. (2015). Suitability of Nafada gypsum for the production of jute fibre reinforced plasterboards. *ATBU Journal of Environmental Technology*, 8(2), 79-92.

[8] Chinta, S. K., Katkar, P. M., Mirji M. J. (2013). Natural fibres reinforced gypsum composites" *International Journal of Engineering and Management Science. I.J.E.M.S. 2013;4(3):318-325.*

[9] Surendra, I.V., Rao, K.V. and Chandra, K. V. (2015). Fabrication and investigation of mechanical properties of sisal, jute & okra natural fiber reinforced hybrid polymer composites. *International Journal of Engineering Trends and Technology*, 19(2), 116-120.

[10] Gesa, F. N., Atser A. R. & Aondoakaa, I. S. (2014). Investigation of the thermal insulation properties of selected ceiling materials used in Makurdi Metropolis (Benue State-Nigeria). *American Journal of Engineering Research (AJER),*3(11); 245-250.

[11] Eric, G. K. and Hensley, B. K. (2017). Analysis of the thermal insulation properties of rice husk ceiling board compared to selected fibre - based ceiling materials used in Yola metropolis, Adamawa State Nigeria. *American Journal of Mechanical and Materials Engineering.* 1(4), 83-88. doi: 10.11648/j.ajmme.20170104.11.

[12] Durai, P., Senthilkumar, B., G, M., & Lakshmanakanth, P. (2023). Investigation of mechanical and dynamic mechanical properties of sisal, jute and banana peduncle fibre composite materials. *Aatcc Journal of Research*, 10(4), 214-222. https://doi.org/10.1177/24723444231161748

[13] Singh, H., Dewangan, B., & Jain, P. (2021). Experimental study on drilling characteristics of the hybrid sisal–jute fibre epoxy composites. *Journal of Micromanufacturing*, 4(2), 157-168. https://doi.org/10.1177/25165984211015413

[14] Girijappa, Y., Rangappa, S., & Parameswaranpillai, J. (2019). Natural fibers as sustainable and renewable resource for development of eco-friendly composites: a comprehensive review. Frontiers in Materials, 6. https://doi.org/10.3389/fmats.2019.00226

[15] Gon, D., Das, K., Paul, P., & Maity, S. (2013). Jute composites as wood substitute. *International Journal of Textile Science*, 1(6), 84-93. https://doi.org/10.5923/j.textile.20120106.05

[16] Alajmi, A., Abousnina, R., Shalwan, A., Alajmi, S., Alipour, G., Tafsirojjaman, T., … & Will, G. (2022). An experimental and numerical investigation into the durability of fibre/polymer composites with synthetic and natural fibres. Polymers, 14(10), 2024. https://doi.org/10.3390/polym14102024

[17] ASTM C473-07 (2004). Standard Test Methods for Physical Testing of Gypsum Panel Products. ASTM International, West Conshohocken, PA, USA.

[18] ASTM C1396M-11 (2004). Standard Specification for Gypsum board. ASTM International, West Conshohocken,PA, USA.