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Development And Analysis of Waste Human Hair Fiber Reinforced Composite

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ABSTRACT

Feathers from other birds and animals, including human hair and chicken feathers, are frequently regarded as waste materials, and popular disposal techniques like burning and burying them contribute to environmental contamination. Nevertheless, fiber-reinforced textile composite materials can be made from these waste resources Human hair fibers were used to create a composite in this study, and the mechanical and physical characteristics of the final composite sample were examined. Different ratios of unsaturated polyester resin to human hair were used to construct the composite sample, which was then examined according to predefined parameters for its mechanical and physical properties. The composite material, consisting of human hair fibers and a polymer matrix, exhibited favorable outcomes by displaying high strength and stiffness, making it appropriate for the production of lightweight ceiling boards for homes. The study revealed an initial increase in both flexural and compressional strength for the first two composite samples, followed by a gradual decrease as fiber content was increased while reducing resin content. Additionally, the research indicated a proportional rise in water absorption percentage with increased fiber content and decreased polyester resin in the composite. Overall, these results point to the possibility of effectively producing a composite material with high strength and rigidity through the incorporation of human hair fibers as reinforcement in a polymer matrix. This material would be perfect for lightweight home ceiling board applications.

Keywords: Composite, Human hair fiber, Matrix, Unsaturated polyester, Epoxy

1. INTRODUCTION

Human hair, which is frequently considered a waste substance worldwide, clogs waste streams and causes environmental problems. This debris is typically regarded as a byproduct, along with chicken feathers and other animal hair, and disposal techniques exacerbate environmental contamination [1]. It is necessary to address the inefficient use of these materials by implementing utilization mechanisms where none now exist and by correcting current practices. Important factors like knowledge, skills, technical needs, and potential markets are investigated in order to increase the usage of hair in new contexts [2]. Despite being abundant worldwide, human hair is often perceived as useless in many societies. Consequently, it ends up in municipal waste streams, persisting for an extended period due to slow degradation, occupying significant volumes of space [3].

One example of how an environmentally conscious approach approaches the problem of repurposing waste resources is the development of composite materials that use human hair as a matrix component. This novel approach yields high specific strength and significant waste utilization when combined with other reinforcing materials, offering a cost-effective way to make high-strength composites [4].

Because of their accessibility, lightweight nature, affordability, and environmentally benign qualities, fiber-reinforced composites—which are made of fibers and a matrix—represent a rapidly expanding industry [5]. Numerous research works have explored the fabrication, characterization, and applications of human hair [7]. In this research, a composite was created using human hair fibers, with a subsequent analysis of the mechanical and physical properties of the developed sample.

1.1 Statement of the problem

Worldwide, human hair is regarded as waste, and Ethiopia is no exception. This causes serious environmental problems in urban waste streams. Burning the material releases harmful gases and offensive odors, including ammonia, carbonyl sulphides, hydrogen sulphides, sulphur dioxide, phenols, nitriles, pyrroles, and pyridines. The material is frequently disposed of in cities and towns throughout the world [19].

1.2 Objective of the study

The development and performance analysis of an unsaturated polyester resin composite reinforced with human hair fiber are the objectives of this work. The study focuses on the manufactured composite's mechanical and physical characteristics.

1.3 Scope of the study

The scope entails developing reinforcement for composites using human hair fiber followed by an investigation into the mechanical and physical properties of the composite. Further tests are excluded due to laboratory constraints.

2. LITERATURE REVIEW

Volkan (8) identified and characterized the exceptional properties of human hair such as its unique chemical composition, slow degradation rate, high tensile strength, thermal insulation and elastic recovery which has led to many diverse uses.

Jain [9] studied hair fiber-reinforced composite with epoxy resin and concluded that there is an increment in properties of composite according to the percentages of hairs by weight increase. The addition of human hair to the composite improves various properties of composite like tensile strength, compressive strength, binding properties and micro cracking control.

Therefore, human hairs are in relative abundance in nature and are non-degradable, providing a new era in the field of fiber-reinforced composite.

Hernandez [10] studied keratin which is a fiber found in hair. Keratin fiber has a hierarchical structure with a highly ordered conformation and is by itself a bio composite product of a large evolution of animal species. He concluded that the keratin fibers show an eco-friendly material that can be applied in the development of green composites. Hair fiber durability and resistance to degradation under environmental stress comes from the linkage between the cysteine molecules and keratin proteins that form disulfide chemical bonds. These bonds are very strong. Velasco [11] studied the anatomy and physiology of hair fiber and concluded that hair fiber is composed of three main structures: cuticle, cortex and medulla. The main factor to be considered in the human hair is the high amount of the amino acid cysteine, which may be degraded and afterward maybe reoxidized under a disulfide bonding form. This is the basis for the permanent curling process. Cysteine is very stable; this is the reason why human hair may be found relatively intact even after several years after the death of an individual.

The unique properties of human hair such as its unique chemical composition, slow degradation rate, high tensile strength, thermal insulation, elastic recovery, scaly surface and light weight have led to many diverse uses. Human hair varies in terms of five parameters: length, color, straightness or curliness, hair damage and contamination [12].

A thermoplastic can be reheated, softened and molded into a new shape while the thermoset, once molded into a shape, cannot be recycled [13].

Transporting and storing thermoplastics is much simpler than that for thermosets. This is because they have, unless limited by some additive or other substance, an unlimited shelf life. A decrease in cycle times also makes them more attractive since thermoplastics do not require an extra mixing step or the long curing times of thermosets. Examples of thermoplastic resin are polypropylene, polyethylene; polyamide polystyrene polyvinyl and chloride are the common thermoplastic resin [14].

Thermoset resin: Much of the early work used thermosetting resins as matrix material for composite production. In the last few years there has been renewed interest in these products for use in automotive applications. Epoxy and phenolic thermosetting resins are known to be able to form covalent cross-links with plant cell walls via -oh group [15].

Unsaturated polyester resins are an important class of high-performance engineering polymers used in numerous applications primarily in compression molding (sheet molding compounds), injection molding (bulk molding compounds), resin transfer molding (RTM), Pultrusion, filament winding and hand lay-up process.85% of the fiber reinforced polymer (FRP) products such as boats, car and aircraft components and chairs were manufactured using polyesters [16].Curing agents play an important role in the curing process of unsaturated polyester resin because they relate to the curing kinetics, reaction rate, gel time, degree of cure, viscosity, curing cycle, and the final properties of the cured products.

Hand lay-up: Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal [17].

The simplest technique to manufacture a composite is called lay-up moulding, wet layup or laminating. This method is performed by applying (by hand) layer upon layer of fibers (or mats of fibers) with resin in between on a shaped surface. This is repeated until the desired thickness is obtained after which pressure is applied, normally by hand rolling [18].

3. MATERIALS AND METHODS

a. Collecting and cleaning: Human hair fibers were collected from barbershops. The separation of hair from other waste depends on the source, as the collected hair may contain various foreign materials, such as dust, cotton, and tissue. Subsequently, the hair is washed with detergent to remove impurities and then dried under the sun.

b. Mold preparation:

Fig 1. Drying of human hair strands

Figure 2. Plate and Lid for Molding

There is now a mild steel mould made especially for making laminate sheets measuring 300 by 300 by 10 mm. The mould releaser, cover frame, and base plate are among its key parts. After applying a release agent to the walls, base plate, and lid surfaces of the mould, they are allowed to dry. In addition to enclosing and compressing the fiber following resin application, the base plates and lids keep debris out of the composite pieces throughout the curing process.

c. Composite preparation using hand lay-up process: In this study, one of the oldest and most basic open moulding techniques used in composite production is the hand lay-up procedure. The hand-lay-up approach is preferred because it is particularly appropriate for large components and is labor-intensive due to its low volume. To fill the prepared mold, an unsaturated polyester resin mixture is applied along with layers of randomly arranged (chopped) human hair. The process involves starting and ending each layer with resin.

During fabrication, chopped fibers are trimmed to the proper size for depositing in the mould. For every composite sample, the resin and fiber are precisely weighed using pre-established parameters. After that, the liquid is poured into the mould cavity that has been filled with chopped human hair fiber. The mould is then firmly fastened with nuts and bolts.

After each layer, chopped strands of reinforcement are cut and positioned on the mold's outside. A liquid thermosetting polymer is completely combined with a hardener (curing agent) in a weight ratio of 10:1, and then the mixture is poured over the mold's surface over the chopped strands. A brush is used to spread the solution uniformly. A roller brush is then used to make sure that the polyester resin is distributed evenly after a plastic sheet is placed on top. To further facilitate release, gel is sprayed on the inner surface of the top mold plate, which is then placed on the stacked layers. Finally, the composite specimens undergo pressing using a hydraulic press to guarantee penetration of the polyester resin into the porosity of the chopped strands.

d. Sample preparation: To prepare the sample, chop the reinforcing strands and place them on the surface of each sheet of the mould. Then, the surface of the previously put chopped strands in the mould is carefully coated with a liquid thermo-setting polymer that has been carefully combined in a weight ratio of 10:1 with a hardener (curing agent). Using a brush, distribute the solution evenly. The polyester resin is more easily distributed once a plastic sheet is placed on top and a roller brush is used. Release gel is sprayed on the inner surface of the top mold plate, which is then positioned on the stacked layers. Polyester resin composites reinforced with human hair are fabricated with varying fiber-to-resin ratios of 30/70%, 40/60%, 50/50%, and 60/40%, respectively. This percentage is a randomized sample preparation ratio.

e. Material composition:

Table 1. Different combinations of human hair, filler, and resin

Specimen Code	Human hair fiber weight (%)	filler (%)	Resin weight (%)
FR-316	30	10	60
FR -415	40	10	50
FR -514	50	10	40
FR -613	60	10	30

In this study, human hair was used to create polymer composites. Composite plates were then compared for every composition. The terminology listed in Table 1 is used to distinguish between various compositions.

e. Compression and curing: Room temperature was used for the curing procedure, and a constant pressure of 5 MPa was maintained.

Fig 3a. Sample created with a composition of 30% human hair and 70% resin and filler.

Fig 3b. Sample created with a composition of 40% human hair and 60% resin and filler

Fig 3c. Sample created with a composition of 50% human hair and 50% resin and filler.

Fig 3d. Sample created with a composition of 70% human hair and 30% resin and filler

Following the hardening process, the samples were extracted from the hydraulic pressing machine, and specimens were carefully removed from the mold to prevent any breakage. The sides of the specimens were then processed on a grinding machine for finishing.

f. Specimen for test: The sample was cut using a metal saw machine blade, which was then employed to cut each composite sample into smaller pieces for various experiments. After the specimen was cut into the desired dimensions based on the respective standards, the mechanical and physical properties of the composite were tested in accordance with ASTM standards.

Fig 4. Preparations of samples for testing

4. RESULTS & DISCUSSION

This chapter presents the results of mechanical and physical properties of unsaturated polyester resin composite reinforced with human hair. Also, the effect of fiber parameters such as fiber loading on mechanical behavior of the fabricated composite material is discussed here.

a. Flexural Strength Test Result for Composite Sample: The findings show that changing the ratio of fiber to resin has a significant effect on the flexural strength of unsaturated polyester composites reinforced with human hair fiber. The graph presents a noteworthy test result, showing that a blend of 40% human hair fiber, 50% polyester resin, and 10% filler is required to get the maximum flexural strength in FR-415. The flexural strength of the composite is strongly influenced by increasing the fiber content.

Table 2. Average flexural outcome of the composite sample

Sample code	Composition (wt, in %)		Flexural strength (MPa)
	Human hair fiber	Resin	
FR-316	30	60	177.3
FR -415	40	50	183.0
FR -514	50	40	174.2
FR-613	60	30	166.7

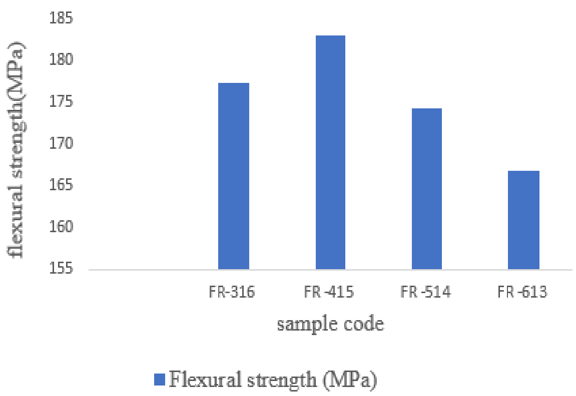

Fig 5. Graphical depiction of flexural strength for a composite sample

The ability of the fiber material to withstand the load during the three-point bending test is improved by increasing the fiber content and decreasing the amount of matrix, according to statistical analysis of flexural strength across several composite samples. This effect stems from the reduction in the matrix material, which binds individual fibers, thereby acting as a load-carrying component. The lower value of flexural strength at higher fiber content may be attributed to the insufficient matrix in the composite, which is unable to effectively transfer the load to the fiber.

b. Compressive strength test result for composite sample: According to the figure, the compressive strength of an unsaturated polyester resin composite reinforced with human hair fiber is significantly impacted by changes in the fiber/matrix composition.

Table 3. Average compressive strength for composite sample

Sample code	Composition (wt, in %)		Compressive strength (MPa)
	Human hair fiber	Resin	
FR-316	30	60	103.2
FR -415	40	50	108.3
FR -514	50	40	101.5
FR-613	60	30	96.7

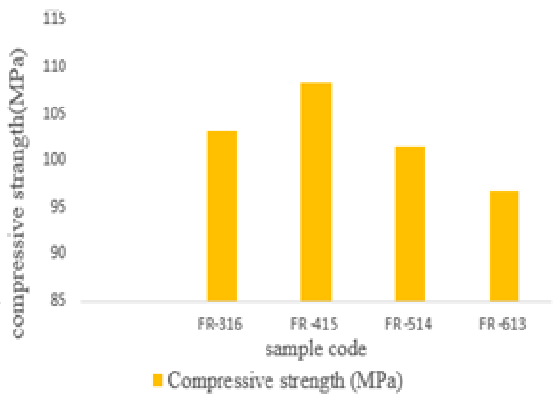

Fig 6. Graphical depiction of compressive strength for a composite sample

Weak fiber-to-fiber interaction, poor fiber dispersion in the matrix, and a low proportion of unsaturated polyester resin, which passes the load to the reinforcement material, are likely the causes of the inferior compressive properties at greater fiber content.

c. Water absorption test result for composite sample: The findings show that the fiber composition significantly affects the composite sample's capacity to absorb water. Higher fiber content causes the percentage of water absorption to rise, whereas more polyester resin, the matrix ingredient, causes the composite sample's water absorption to drop. Weak fiber-to-fiber contact is the reason why the rate of water absorption reduces when the fiber's volume fraction drops.

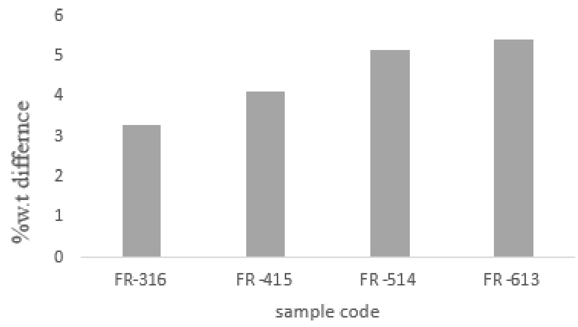

Fig 7. Graphical depiction for water absorption in composite sample

5. CONCLUSIONS

The human hair fiber-reinforced polyester composite, created with a basic hand lay-up approach, shows favorable mechanical and physical properties, according to analytical and experimental examinations. It is advised to use it for light-duty applications like ceiling boards. The findings show that too many fibers in composite materials might weaken their mechanical qualities because there is insufficient bonding between the fiber and matrix at their contact. The load cannot be transferred to the bonded fibers as a result of this disturbance. The experimental results of the polyester resin composite reinforced with human hair have been analyzed using statistical software (SPSS) to determine their significance or lack thereof.

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