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Short Communication

Design and fabrication of natural woven fabric reinforced epoxy composite for household telephone stand

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Abstract

In the recent era there has been an increasing interest in composite materials for its applications in the field of aerospace, sports, industries, medical, and in many other fields of engineering including household furniture. This paper deals with the design and fabrication of banana woven fabric reinforcement epoxy composite for household telephone stand. A systematic approach of total design process is presented for better understanding of the best design concept for the product. The fabrication process of composite telephone stand using banana woven fabric is also described in this paper.

Keywords: Natural fibre composite; Household furniture; Total design

1. Introduction

The first known composite material in human history was clay reinforced by straw used in building construction developed by the ancient Egyptians approximately 3000 years ago. In fact, this composite was a natural fibre composite. However, with the advancement of materials technology, materials with better performance, such as metals, plastics, ceramics and even man made fibre composites were intensively being used and the use of natural fibre composite was abandoned for very long time.

Until recently, the use of natural fibre composites starts gaining popularity in engineering applications. This is due to the fact that this material possesses characteristics that are comparable to conventional materials. Properties like light weight, low material cost, renewable and environmentally friendly are among the most important selling points of this material. Despite its strength and durability are somewhat poorer than conventional materials, these properties can be improved by interfacial treatments [1].

In the past various studies have been carried out on natural fibre composites. Rowell [2] explained availability of natural fibres in the form of (1) bast or stem fibres, (2) leaf fibres, (3) core, pith or stick fibres, (4) seed hair fibres and (5) other plant fibres. Flax, hemp, jute, kenaf, ramie, roselle and urena are examples of bast fibres. While banana, palm, sisal, henequene, abaca, pineapple, cantala, caroa are leaf fibres. Seed fibres category includes coir, cotton, kapok and milk weed floss. Detail explanation of different natural fibres can be found elsewhere [3,4]. Oil palm fibre has been studied and used for various applications viz., furniture and building industries as a replacement of solid wood and plywood. A study has been undertaken to explore the possibility of incorporating pulverized fly ash (PFA), rice husk ash (RHA) and natural rubber latex in oil palm frond (OPF) fibre cement composites [5]. The oil palm frond fibre cement composite produced with the cement replacement up to 30% had reduced strength properties of the composite. Yusof et al. [6] use the oil palm fibre in fibre wood and tested for water absorption, strength properties, modulus of elasticity and finally compared it with rubber wood. They discovered that water absorption ranged between 61% and 70% and fibre wood contains less than 50% oil palm fronds

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exhibits better strength properties. Fuad et al. [7] investigated the new type wood-based filler derived from oil palm wood flour (OPWF) for bio-based thermoplastics composites by thermogravimetric analysis and the results are very promising.

Coconut fibre (coir) is the seed hair fibre obtained from the outer sheel of the coconut. It is resistant to abrasion and can be dyed. It is used to make brushes, fishnets, marine cordage [4]. Herrara-Franco et al. [8] illustrated the feasibility of coir (coconut fibre) as reinforcing fibre in different thermosetting and thermoplastics matrices such as phenol–formaldehyde, unsaturated polyester, epoxy, polyethylene and natural rubber. Kasim [9] and Sapuan et al. [10] carried out investigation on the mechanical properties of coconut fibre composites. The resin system used was epoxy. The coconut fibres were treated with alkali, acetylenes, peroxide, stearic acid and potassium permanganate and tested flexural and tensile properties.

Jute fibres have received much attention in the field of plant based fibre reinforced composites because of their low cost and biodegradability [11,12]. The jute composites can be used in everyday applications such as lampshades, suitcases, paperweights, helmets, shower and bath units. They are also used for covers of electrical appliances, pipes, post-boxes, roof tiles, panels for partition and false ceilings, bio-gas container. Jute fibre can be combined with various thermoset such as unsaturated polyesters, vinyl esters resin and thermoplastics such as polyethylene, polypropylene and polystyrene but in the latter, the application is very limited due to poor adhesion to hydrophobic thermoplastics.

Sisal fibre is fairly coarse and inflexible. It has good strength, durability, ability to stretch, affinity for certain dyestuffs and resistance to deterioration in seawater. Sisal ropes and twines are widely used for marine, agricultural, shipping and general industrial use. Belmeres et al. [13] found that sisal, henequen and palm fibres have very similar physical, chemical and tensile properties. Cazaurang et al. [14] carried out a systematic study on the properties of henequen fibres and pointed out that theses fibres have mechanical properties that are suitable for reinforcing thermoplastic resins. Ahmed et al. [15] carried out research work on filament wound cotton fibre reinforced for reinforcing high density polyethylene (HDPE) resin. Khalid et al. [16] also studied the use of cotton fibre reinforced epoxy composites along with glass fibre reinforced polymers. They conducted experimental and finite element analysis study of the filament wound cotton and glass fibre reinforced composites. The former is carried out on compression mode and the latter was carried out using PAFEC* software.

However, none of the above researchers have studied the use of woven roving banana-based fibre composites in the development of household furniture. Therefore, a novel study with the aim of design and fabrication of a household telephone stand using banana woven fabric reinforce epoxy composite is presented in this paper.

2. Advantages and disadvantages of natural fibres and glass fibres materials

The advantages and disadvantages matrix of natural fibres and glass fibres materials explained in a tabular form in Table 1.

3. Total design process of banana woven fabric composite

Total design process involves stages that are distinct and is a total sequence of design activities from market needs to sale. A fundamental total design model is shown in Fig. 1. In the design of composite telephone stand, all the activity of total design (except for sale) was carried out. Brief conceptual design of telephone stand is described. Detail design in the form of final drawing is also presented. Fabrication of composite telephone stand is finally presented.

3.1. Product design specification

Product design specification is a set of the requirements of the product that to be met at the end of the product development. Fig. 2 shows the elements of Product design specification (PDS) was considered in designing the telephone stand. The PDS can be summarised as:

Table 1
Advantages and disadvantages matrix [17]

Natural fibres		Glass fibres	
Advantages	Disadvantages	Advantages	Disadvantages
1. Abundant source	Non-uniform fibre sizes	Cheap, uniform fibres are easily made	Untreated, forms poor interface with matrix material
2. Strong	Not suitable for high temperature uses	Strong	
3. Biodegradable			Non-biodegradable
4. Low health risks			Health risks

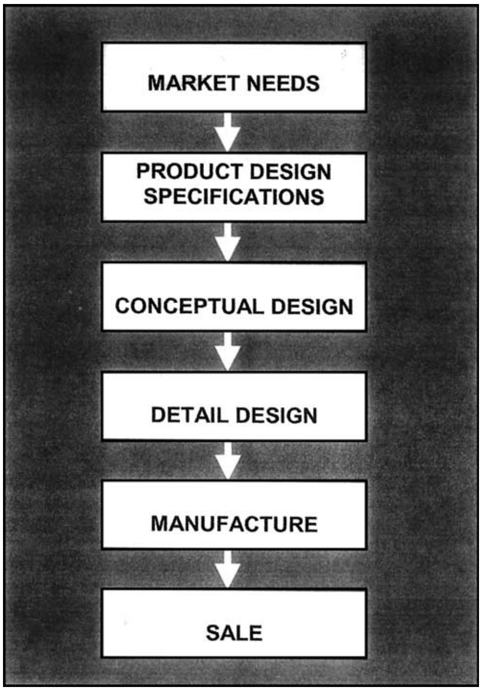


Fig. 1. A fundamental total design model.

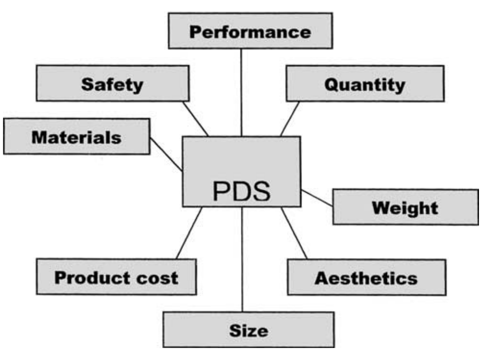


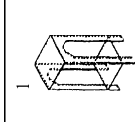
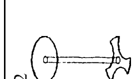
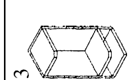
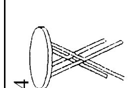
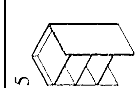
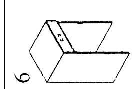
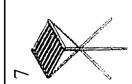
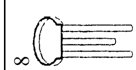
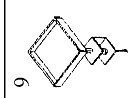
Fig. 2. The product design specification for composite telephone stand.

- Will contain all facts relevant to the product outcome.
- It must also avoid predicting the outcome.
- The restraints must be realistic.
- All areas involved in the product introduction process must. participate in its generation.
- It is evolutionary document, but can only be amended with the agreement of all involved.
- It must be written document.

3.2. Conceptual design

Nine concepts of telephone stand were developed. Then these concepts were evaluated based on certain design criteria taken from the product design specifications. The matrix evaluation chart for selecting the best concept is shown in Table 2. From this table, concept 1 shows the highest score compared to the other concepts

Table 2
Conceptual design chart, for selecting the best design of telephone stand

Concept		1		2		3		4		5		6		7		8		9	
																			
Characteristic	C	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Stability	5	5	25	4	20	4	20	5	25	3	15	5	25	5	25	4	20	3	15
Cost effective and cheap	5	4	20	4	20	4	20	5	25	5	25	3	15	5	25	3	15	4	20
Ergonomic design	5	5	25	5	25	3	15	5	25	4	20	5	25	3	15	4	20	3	15
Low setup time	4	4	16	4	16	3	12	4	16	4	16	3	12	4	16	3	12	5	20
Less space needed	4	4	16	4	16	5	20	4	16	5	20	4	16	3	12	3	12	4	16
Less complex	3	5	15	5	15	3	9	4	12	3	9	4	12	2	6	2	6	5	15
Portability	3	5	15	4	12	4	12	3	9	4	12	4	12	3	9	3	9	2	6
Total score		132		124		108		128		117		117		108		94		107	

Note. C means the weightage for the characteristic. W means the score of the concept. S is the product of weightage and score of the concept.

and it was chosen as the best concept to be developed further.

3.3. Detail design

Detail drawing of selected concept of composite telephone stand is shown in Fig. 3. An important activity in this study is on the development of woven roving banana fibres. The properties of the banana fibre are shown in Table 3. Banana fibres are abstracted from matured banana trunk after the fruit bunch is plucked to avoid wastage. Then, it is placed under sunlight for drying. The natural drying process took up to about two weeks. The dried banana trunk is then soaked in water. The fibres were then dried under sunlight. To orientate the fibres in the composite

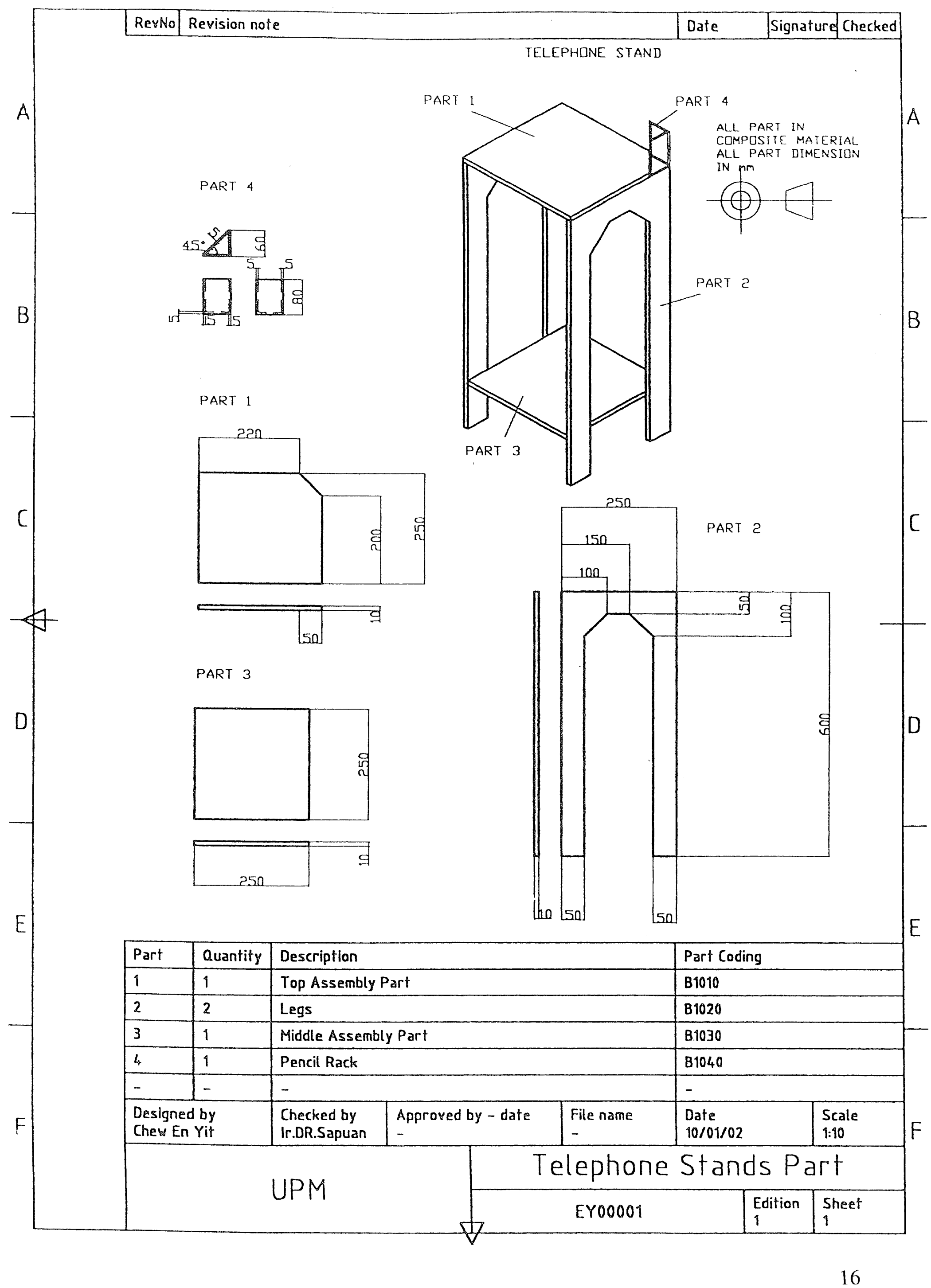


Fig. 3. Detail design for telephone stand.

Table 3
Properties of banana fibre [18]

Width or diameter (mm)	80–250
Density (g/cc)	1.35
Volume resistivity at 100 V (W cm × 10^5)	6.5–7
Elastic modulus (G N/m^2)	8–20
Elongation (%)	1.0–3.5

material, dried banana fibres are woven. It was hand-woven, soft but flexible.

The matrix used to fabricate the telephone stand is epoxy 3554A. Its density is 1.15 g/cm^3 and was mixed in a container with hardener 3554B of density 1.05 g/cm^3. The ratio of mixture of matrix and hardener is 4:1 by weight. The colour of this mixture is transparent yellow. In stirring the mixture, it was ensured that gentle stirring developed no air bubbles. If the bubbles exist, they result in porosity or defect in the final product.

4. Fabrication of composite telephone stand

The mould used in this study is made from concrete coated with a plastic layer. It is open mould and contain the cavities of the components. The detail drawing of the mould is shown in Fig. 4. Separate moulds are needed

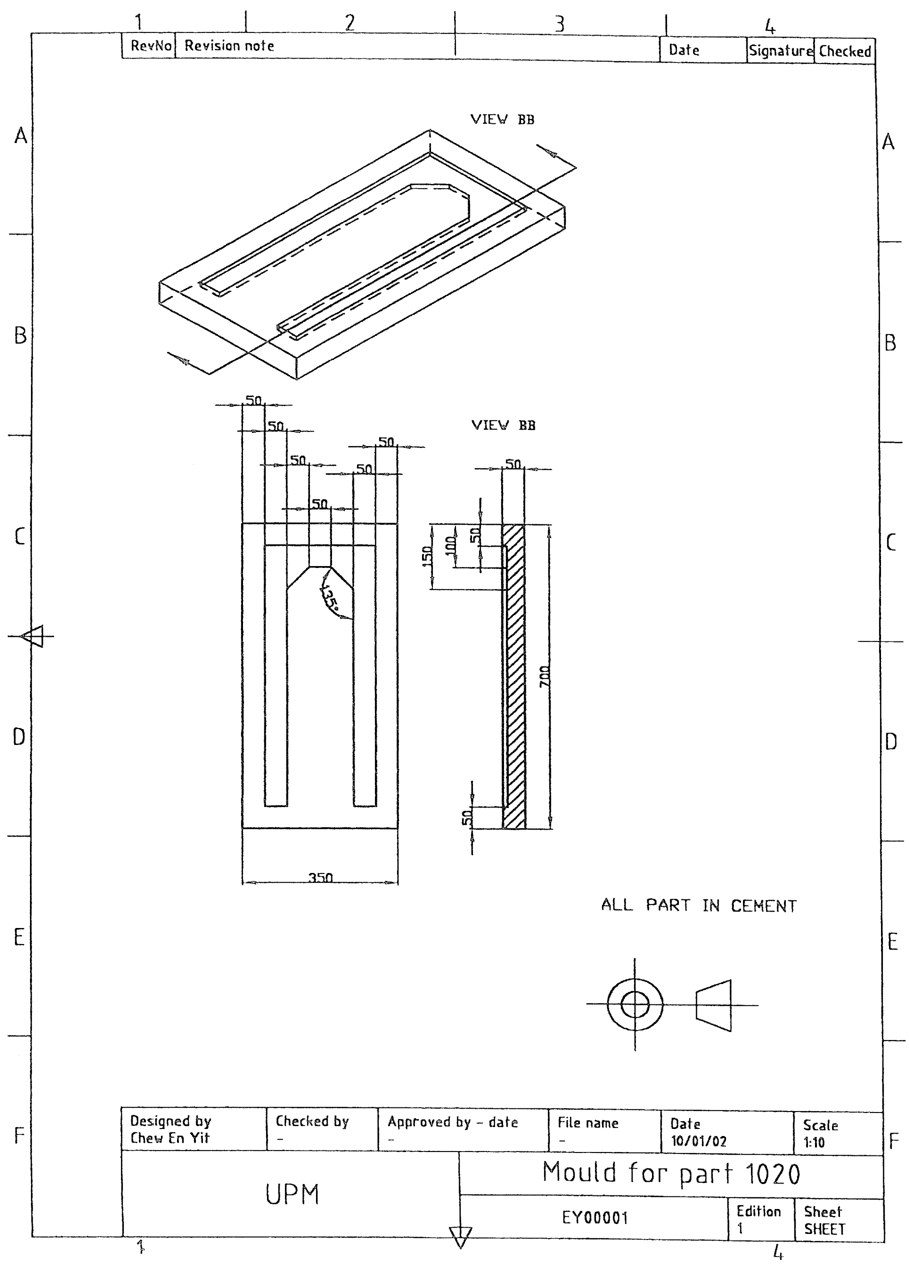


Fig. 4. Detail drawing of the mould used during fabrication of telephone stand.

for horizontal plates and vertical stands. Initially epoxy and hardener were mixed as described earlier. The mould was cleaned and dried and release agent was laid on the mould inner surface. The mixture of epoxy and hardener was laid up using a brush onto the mould inner surface. Then the banana woven fabric was added. This process is repeated until four layers of epoxy and fibre were obtained. Thereafter, the composite was consolidated and left at room temperature for 24 h for curing. Finally, the composite was detached from the mould.

Mechanical fastener was used for joining the vertical stands and horizontal plate. The slotted countersunk screws with 1/4 in. length were used with L type PVC bracket to join the top and middle plates to the vertical stands of the product.

The fabricated telephone stand has smooth finishing surface, is unique in presentation and aesthetically pleasing because of woven banana fibre is transparent. The telephone stand is golden brown in colour and can easily be matched with typical colour of furniture. Its dimension is 25 cm × 25 cm × 60 cm and is very compact. It weighs only 3.4 kg and is portable. Although it is light but stable and does not topple easily. The fabricated banana fibre composite telephone stand is shown in Fig. 5. The telephone stand is suitable for both domestic and office use. A telephone can be placed on the top layer equipped with a pencil container for keeping pencils and pens. The bottom layer of the telephone stand can be used to place telephone directories for user references.

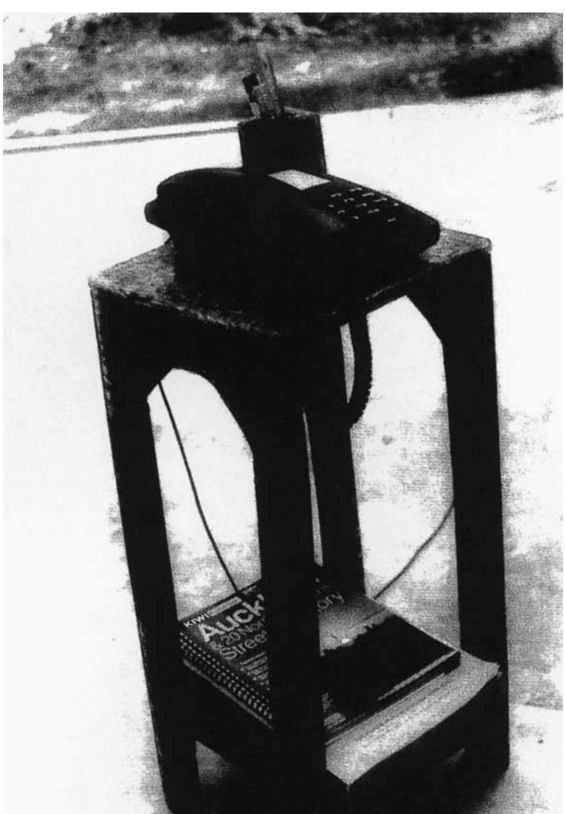


Fig. 5. Actual banana woven fabric composite telephone stand.

5. Conclusions

- In this paper the design concept, detail design and fabrication of woven banana fabric composite telephone stand are presented. The fabricated telephone stand is unique in presentation and aesthetically pleasing, golden brown in colour and can easily be matched with typical colour of furniture. The telephone stand is suitable for both domestic and office use.
- Banana fibre is a feasible reinforcement to form reinforced composite as an alternative and new material for household furniture applications at low cost.
- It is possible to replace conventional metallic, non-metallic, wood and plastic materials by natural fibre composite for telephone stand.

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