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Preparation of transversely isotropic test specimen of natural FRP composite - an innovative approach-II

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Abstract
Fiber Reinforced Plastic (FRP) composites can be broadly classified as synthetic and natural, based on the type of fibers incorporated. Abundantly available natural fibers like toddy palm, sisal, jute and banana are attracting the attention of researchers due to ever increasing demand for lighter, stronger and eco-friendly materials from the industry. However, natural fibers are limited in length, not so uniform in size and behave differently in different atmospheric conditions. Added to this, the inherent tendency of natural fibers to twist and curl in dry conditions poses many problems to researchers while preparing test specimens. Researchers in general and academicians in particular are handicapped by non-availability of relevant literature on fabrication techniques to prepare natural FRP composite test specimens close to their analytical models. Present paper addresses typical problems faced by researchers during preparation of unidirectional continuous fiber reinforced composite test specimen ensuring transversely isotropic nature. Using simple hand tools coupled with a few precautions taken as described herein, prospective researchers can condition natural fibers and prepare composite specimen to suit their requirements.

Keywords: FRP, twist and curl, conditioning, transversely isotropic.

INTRODUCTION

Though not directly in composites, natural fibers have been in extensive usage in the history of mankind since ages. Bamboo reinforced mud walls by ancient Indians (even now) and straw bricks used in Egypt by Israelites are some of the examples. 1930s have seen synthetic fibers like glass fiber taking lead obviously due to their superior strength and other useful properties. 1970s saw the emergence of much superior fibers like carbon, boron and ceramic that pushed the scope of synthetic fibers further. However, the hazardous nature of synthetic fibers and the eventual damage being caused to the nature is restricting their usage in consumer products. Hence, natural fibers have been gaining importance in the light of demand for biodegradable composites. In an effort to establish a data base on mechanical properties of natural fibers in the lines of synthetic fibers, the authors are working on micromechanical analysis of FRP composites (natural and synthetic), particularly in estimating the elastic properties of the constituents from known composites. The work requires the fabrication of unidirectional continuous fiber reinforced composite samples, ensuring transversely isotropic nature. This requires placement of reinforcing fibers in a parallel and straight line orientation in addition to meeting many other specifications as per standards. The present work elaborates on the techniques required for dealing with natural fibers.

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Sisal, Jute, Toddy palm, and Banana fruit bunch fibers are some of the abundantly available and extensively used plant (natural) fibers in India as well as in other tropical countries of the world. However, the usage of these fibers is limited to applications like nets, yarn, ropes and bags. Plant fibers are non-hazardous and have more specific strength than synthetic fibers. In addition natural Fibers are eco friendly, economical, lighter and bio-degradable due to which reason they qualify as a replacement for some components in the manufacturing sector and a safe alternative for domestic applications like false ceilings and wall panels. However, plant fibers are limited in length and suffer from non-uniformity in fineness. In addition, it is difficult to handle these fibers due to their inherent tendency to twist, curl and absorb moisture. This necessitates researchers to condition the fibers skillfully to suit their requirements before incorporating into test specimen.

This paper is a sequel to a previous paper by the same authors that dealt with problems associated with synthetic fibers (glass fiber). Since the problems associated with natural fibers are quite different from that of synthetic fibers in many ways, they are being dealt separately in this paper. Synthetic fibers are uniform in size, too fine (minute in cross section), unlimited in length and straight. The strength of synthetic fiber is augmented by their large surface area available for bonding with matrix (due to high fineness) and so the resulting composites are superior in strength and performance in comparison to natural FRP composites. Natural fibers are relatively larger in cross sectional area (lesser in fineness) and are not quite uniform in size resulting in less surface area available for bonding. Also, the hydrophilic nature of natural fibers necessitates chemical treatment to make them compatible with the resins used. Natural fibers require a surface treatment to improve surface roughness to achieve better bonding. However, natural fibers come into use when economy, eco-friendliness and bio-degradability are prime considerations and which has become order of the day.

MATERIALS AND METHODS

Natural fibers are lighter and the specific gravity of most of them falls around 1.0 as against 2.5 of synthetic fibers. Coarse in nature, natural fibers obviously have less surface area available for bonding. Hence, it requires more understanding of fiber's behavior and surface texture to achieve better bonding with matrix. Also, natural fibers are slightly greasy by nature and are usually available (after retting) with pith sticking all around, which does not contribute to the strength of the fiber. Hence, fibers are to be cleaned off pith and mercerized for eliminating greasy matter for improved surface texture and bonding. The following procedure is adopted to make natural fibers fit for incorporation in matrix.

- Fibers are soaked initially in a mild detergent soap solution for an hour and are thoroughly agitated and combed (hackling) within the soap bath to remove larger part of the associated dirt and pith. Then wet fibers are pulled through a tight cloth orifice, one at a time to remove the remaining pith from fibers.
- The fibers are then soaked in alkaline (2% NaOH) bath for 1 hr. at room temperature and are thoroughly washed in distilled water. Further, for neutralization the fibers are soaked in acid bath (2% H_2SO_4) for 30 min. at room temperature and then washed thoroughly in distilled water. Bunches of fibers are placed in a centrifuge for expelling water.
- Fibers are then bunched in groups of 250 or 500 and are wrapped in a dry cotton cloth. This step removes excess moisture and fibers are left wrapped till they are semi-dry. Fibers are then graded based on size and color. Graded fibers, while in semi-dry condition, are combed straight manually to remove curling and twisting and kept bunched as shown in Fig. 1.
- Fully dried natural fibers tend to curl if left free and hence are to be bundled in semi-dry state and wrapped in a cloth. Small bunches containing 250 to 500 individual fibers are held tight with rubber bands at both ends and are cut to required length as shown in Fig. 2. These bunches are then wrapped tight in a clean cotton cloth to keep them straight.
- The fibers are further dried in an oven for 12 hours at 40^0C in wrapped condition and then packed in a polythene bag to keep them free of dust and moisture.

Fig 1. Graded toddy palm fibers

Fig 2. Sisal fibers after bunching

Unlike synthetic fibers, natural fibers behave differently in varying atmospheric conditions and usually tend to curling and twisting as shown in Fig.3. Hence, working with natural fibers demands a controlled atmosphere during preparation of the mold. 28-32^0C temperature along with 55-60% humidity is found to be better. A spirit level, a water mist sprayer and a hair dryer are three extra tools required over and above those used for glass fibers. Mold is prepared with two way glue tape as described in the preceding paper of the same authors [6]. For dimensional accuracy, for holding fibers in place, for leak proof mold cavity and for ease of dismantling, 2- way glue tape is found to be the best alternative for any other molding material. Leveling of the mold bench is utmost important for achieving uniform thickness of the specimen. The width of the tile used as mold base is taken 30mm more than the length of the test specimen to facilitate clamping of the fiber ends as well as to avoid fouling of the edges with C-clamps as shown in Fig. 4.

Fig 3.Dry fibers tend to curl and twist

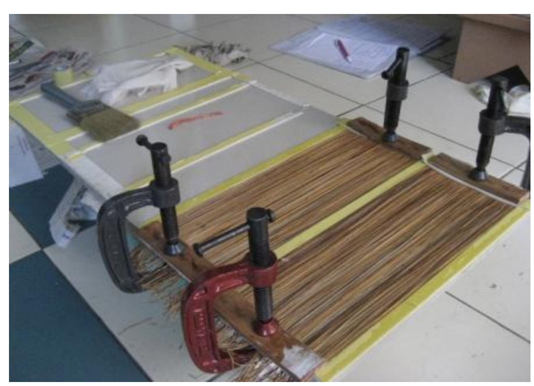

Fig 4. Width of mold base is just enough to avoid fouling with C-clamps

The length of fibers depends on the type of specimen to be prepared. As an example, for a tensile test specimen (as per ASTM) of 250mm long, minimum working length of fibers is found to be 320mm. The extra 70mm is for holding them straight with clamps which ultimately are cut off after the specimen is cast. Linear density of fibers is determined by weighing at least 5 sample groups of fibers of varying numbers but of equal length. The following steps are followed for best results.

- Fibers are graded according to their size (thin, medium and thick).
- Only one grade is selected for making the test specimen. Else, equal number of fibers from each grade are mixed together.
- All fibers are cut to sufficient length and then counted and bunched in 100, 200, 300 and 500 before weighing.
- Based on the linear density, required number of fibers is calculated for any volume fraction.

Weighing is done on a digital weighing machine of 1 mg least count. The volume fraction is computed as it is done in case of synthetic fibers and the number of fibers that go into each mold is determined before setting off to prepare the mold. Required number of fibers corresponding to the target volume fraction are separated and weighed to cross check for the designed volume fraction. Placing of fibers in parallel orientation and sustaining them in position is a painstaking and demanding part of the whole work. The steps for best results are as following.

- Fibers are sprayed with a mist of distilled water sufficient enough to make them supple For handling and are wrapped in a cloth. Before setting off for sticking them to the mold boundary, the number of fibers per unit width is calculated. Fibers are held aligned and stuck one after the other to the glue tape as shown in Fig. 4, while they are still supple, with moderate pre-tension applied by both the hands. Cross checking of number of fibers per unit length is done progressively
- Both ends are further held firmly with another layer of glue tape on top. A piece of 25 mm wide wooden reaper of sufficient length is placed over one end of the mold and fixed with one or two C-clamps as shown in Fig.5. While sustaining this state, the other end is also clamped firmly as shown.

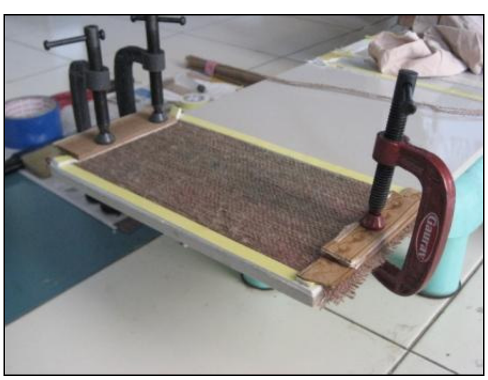

Fig 5. Firmly clamped fibers kept in straight alignment

- Clamped fibers are blown with warm air using a hair dryer initially for two to three minutes and the mold set up is left to dry on its own for 45 to 60 minutes in a conditioned room with 36^0C temperature and 55% humidity. C-clamps are tightened progressively to ensure the fibers are firmly in straight lines before pouring.

Resin (matrix) is prepared as per the instructions of the supplier. 200ml paper cups and 10ml syringes are useful tools for handling the accelerator, catalyst and resin. Thorough mixing while avoiding agitation is done skilfully without forming air bubbles. Pouring is done keeping the cup close to the mold by starting at the centre of the mold and working towards outer edges. The even spread of resin in all directions is observed, which is an indication of horizontality of the mold that results in uniform thickness of the specimen. The specimen is removed after allowing three hours of setting time. Cutting off extra long fibers is done with scissors. Test specimen is cut as per dimensions on laser cutter and sufficient care is taken to avoid burning of fibers by adjusting the intensity of laser beam with a few trials.

CONCLUSIONS

While extensive literature is available on testing and analysis of FRP composites, very little information is available on the methods of fabricating a truly representative FRP test specimen particularly with natural fibers. This paper elaborates on various new techniques for preparing continuous natural fiber reinforced test specimen. Conditioning of natural fibers to the requirement, which otherwise pose many problems during molding, is presented in detail. Computing and achieving the required volume fraction is discussed in detail. Placing of fibers in parallel orientation for a transversely isotropic specimen, holding them in position till the resin is poured in the mold and other such techniques are tried, tested and presented. Prospective researchers will be able to make appropriate specimens close to their analytical assumptions by following these techniques. The future scope of the work is in the development of techniques for preparation of natural composites using natural fibers and degradable resins.

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