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Effective Recycling and Use of Wood Carving Waste in Wood Industry

Jijin I[1], Rinitha P[1]
[1](*Mechanical Engineering, College of Engineering Thalassery/ CUSAT, INDIA)*

Abstract: *Composites based on natural fibre reinforcement have generated wide research and engineering interest in the last few decades due to their small density, high specific strength, low cost, light weight, recyclability and biodegradability and has earned a special category of green composite. This article reviews the reports based on wooden waste using different fibre as fillers and reinforcements. Various processing methods and conditions like compression moulding, heat treatments are used in the composites productions. Manufacturing industry produces large amount of waste throughout the year. Most of the time these waste ends up in landfills disturbing environmental, economical and social life cycle. Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs; and can be considered as one of the solution to solve manufacturing waste problem. Sustainable design, proper use and reuse of the resources will make wood and other industries more economical and green. Process of recycling waste includes storage, sorting, collection, transportation, recycling and disposing. For recycling wood waste, the water vapour explosion (WVE) process was developed. In this process wood materials were exploded from within by the force of water vapour generated by compression by high pressure and temperature and evaporation of the internal moisture and thus they are separated into small wood elements.*

Keywords: *Autogyro, CNC,Eco-board, NACA Airfoil, Wood carving*

I. Introduction

Wood is the only natural circulating material among principal construction material and is characterized by the storage of carbon dioxide that is absorbed when it was a growing tree. Therefore to lengthen the period between cutting and disposal is important to reduce the amount of carbon dioxide emitted by human induced activities. One of the principal factors that make it difficult to recycle wood waste is that construction wastes are usually disposed of as mixtures of materials, which are difficult to separate. From such wastes, only a small amount of recyclable materials can be obtained, and the way to recycle them is limited to chipping now. The labour cost and energy needed to classify a mixture into components increases there are more components in the mixture. To solve this problem and to promote recycling, materials should be produced b considering the ease of disassembling and recycling it. The promotion of environmental management and the mission of sustainable development have exerted the pressure demanding for the adoption of proper methods to protect the environment across all industries including construction. Construction by nature is not an eco-friendly activity. Construction, renovation and demolition activities lead to the formation of waste. Construction and demolition waste is generated whenever any construction/demolition activity takes place, such as, building roads, bridges, flyover, subway, remodeling etc. It consists mostly of inert and non-biodegradable material such as concrete, plaster, metal, wood, plastics etc. A part of this waste comes to the municipal stream. These wastes are heavy, having high density, often bulky and occupy considerable storage space either on the road or communal waste bin/container. It is not uncommon to see huge piles of such waste, which is heavy as well, stacked on roads especially in large projects, resulting in traffic congestion and disruption.

Composites are one of the most advanced and adaptable engineering materials known to men. Progresses in the field of materials science and technology have given birth to these fascinating and wonderful materials. Composites are heterogeneous in nature, created by the assembly of two are more components with fillers or reinforcing fibers and compactable matrix. A composite material is a material system composed of a suitably arranged mixture or combination of two or more micro- or macro- constituents with an interface separating them that differ in form and chemical composition and are essentially insoluble in each other. At the atomic level materials such as some metal alloys and polymeric materials could be called composite materials since they consist of different and distinct atomic groupings. Material property combinations and ranges have been, and are yet being, extended by the development of composite materials. Generally speaking, a composite is considered to be any multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized. According to the principle of

combined action, better property combinations are fashioned by the judicious combination of two or more distinct materials. Many composite materials are composed of two phases; one is termed the matrix, which is continuous and surrounds the other phase, other called the dispersed phase. The properties of composites are a function of the properties of the constituent phases, their relative amounts, and the geometry of the dispersed phases. "Dispersed phase geometry" in this context means the shape of the particles and the particle size, distribution, and orientation. One simple classification of composite materials is which consists of three main divisions: particle-reinforced, fibre-reinforced, and structural composites; also, at least two subdivisions exist for each. The dispersed phase for particle-reinforced composites is equiaxed (i.e., particle dimensions are approximately the same in all directions); for fibre-reinforced composites, the dispersed phase has the geometry of a fibre (i.e., a large length-to-diameter ratio). Structural composites are combinations of composites and homogeneous materials. The discussion of the remainder of this chapter will be organized according to this classification scheme.

Kannur district has had industrial importance from very early days. With a variety of natural and man-made resources including fertile soil, amenable climate, rich forests, fishing potential and minerals along with road, rail and inland water transport links, the district offers ample scope for the development of industries. Nevertheless, Kannur is an industrially backward district. There is only one major and five mini industrial estates in the district. Keltron Complex, Mangattuparamba and Western India Plywood's, Valappattanam are the two major industries. Western India Plywoods is one of the biggest wood based industrial complexes in South East Asia. The district has 12 medium-scale industries, most of which are either cotton textile or plywood manufacturing. Current project was conducted in Kannur, Kerala to know about the status of wood waste across the district. The district known for its textile and ply wood industries influence in the wood market across the world.Western India ply wood at Valapattanam, Kannur is a major plywood manufacturer who are as a part of the global plywood market. Apart from this more than 21 wood merchants are also playing a major role in the wood industry and supply of wooden composite board and its panels.

This project mainly focuses on the wood industries who use CNC router machine for production or services. At present totally 11 CNC router based wood industry are present in Kannur. Most of them are focussed on the production of membrane doors and some provide wood carving facility to their customers. Black screen wood carving is one among them who are using their router machine for 2D and 3D carving. Thus wastes generated from these industries are also an environmental threat. None of the industries uses a recycling strategy for effective utilization of the waste generated from the machining operates they carry out throughout apart from burning it for steam generation. An autogyro also known as gyroplane, gyrocopter, or rotaplane, is a type of rotorcraft which uses an unpowered rotor in autorotation to develop lift, and an engine-powered propeller, similar to that of a fixed-wing aircraft, to provide thrust. While similar to a helicopter rotor in appearance, the autogyro's rotor must have air flowing through the rotor disc to generate rotation. An autogyro is characterized by a free-spinning rotor that turns because of passage of air through the rotor from below. The vertical (downward) component of the total aerodynamic reaction of the rotor gives lift for the vehicle, and sustains the autogyro in the air. A separate propeller provides forward thrust, and can be placed in a tractor configuration with the engine and propeller at the front of the fuselage, or pusher configuration with the engine and propeller at the rear of the fuselage. The autogyro rotor blade generates lift in the same way as a glider's wing by changing the angle of the air as the air moves upwards and backwards relative to the rotor blade. The free-spinning blades turn by autorotation; the rotor blades are angled so that they not only give lift, but the angle of the blades causes the lift to accelerate the blades' rotation rate, until the rotor turns at a stable speed with the drag and thrust forces in balance. Because the craft must be moving forward (with respect to the surrounding air) in order to force air through the overhead rotor, autogyros are generally not capable of vertical takeoff or landing (unless in a strong headwind).

II. Field Study

2.1 Offsite Study

Current status of CNC router based wood industry in Kannur district known for its ply wood industry is having a competitive situation in the field of the CNC router based production and services. Almost half the portion uses the machine for membrane door production and some are in the field of designing in the wood replacing the conventional hand carving to CNC based carving. Looking to the insight of these industry most of them are restricted to some particular programming or design based on the product they prepare. This situation is based on their lack of knowledge about the performance and the flexibility of the CNC machine. Below given table 1 shows the CNC based company in Kannur along with their basic details.

Table I : CNC based company Kannur with their basic details

Industry name	Machine used	Product and service	Waste management
Blackscreen wood carving, Pallikulam	Air cooled CNC router, Jai industries	2D,3D wood carving and jali cutting	Wood waste are used for house hold and hotel cooking and multi wood waste is dump in industrial area itself
Black screen wood carving, Pazhayangady	Air cooled CNC router, Gundally machines	2D,3D wood carving and jali cutting	Wood waste are used for house hold and hotel cooking and multi wood waste is dump in industrial area itself
Venkateshwara wood, Payyannur	Water cooled CNC machine, Printo machineries	2D,3D wood carving and jali cutting	Wood waste are used for house hold and hotel cooking and multi wood waste is dump in industrial area itself
Ayaan craft works, Kakkad	Air cooled CNC router, Jai industries	2D,3D wood carving and jali cutting	Wood waste are used for house hold and hotel cooking and multi wood waste is dump in industrial area itself
Ayaan craft works, Pilathara	Air cooled CNC router, Jai industries	2D,3D wood carving and jali cutting	Wood waste are used for house hold and hotel cooking and multi wood waste is dump in industrial area itself
Wood pecker, Koothuparamba	Air cooled CNC machine, printo machineries	2D,3D wood carving and jali cutting	Wood waste are used for house hold and hotel cooking and multi wood waste is dump in industrial area itself.
Aisha wood, Pappiniserry	Air cooled CNC router, Jai industries	Membrane door line works	Used in industry boilers
Western India ply wood ltd, Valapattanam	Air cooled CNC router, Jai industries	Membrane door line works	Used in industry boilers
Floral tech, Arayalthara	Air cooled CNC router, Emusmach	Jali cutting	Wood waste are used for house hold and hotel cooking and multi wood waste is dump in industrial area itself
Floral tech, Cherukknu	Air cooled CNC router, Emusmach	2D,3D wood carving and jali cutting	Wood waste are used for house hold and hotel cooking and multi wood waste is dump in industrial area itself
Wood max, Thavam	Air cooled CNC router, Jai industries	Membrane door line works	Used in industry boilers

Fig 1: Waste disposal in other industries

2.2 Onsite Study

2.2.1 Company Profile*:*

Black screen wood carving and interiors is a wood base manufacturing company established in 2009 with its first factory at Pazhayangady, kerala. First CNC based designing and interior company with Gundally CNC router machine having high speed air cooled Italian spindle. The company now put forward one more branch at Pallikulam, Kerala with a CNC router machine of Jai industries, an Indian based CNC router manufacturer in Gujarat. Company mainly uses Artcam pro designing software for designing and toolpath programming. The company mainly aims at providing customers with low cost designing and carving on wood

and wood composite like medium density fiber (MDF), particle board and multiwood. The company reduced the lead time of customer product and made a dramatic changeover from conventional hand carving and designing to a technologically developed and customerised designing and manufacturing wood industry.

a) Product and services

- Home and shop interior
- Kitchen cabinets
- Wood carving
- Jali cutting
- Wooden and wood based furniture
- Home decorative items
- Wall partition
- panelling

Fig 2: CNC router machine

b) Company mission and vision:

Company mission is to provide customers with high quality and dimensionally precise product within low cost and reduced lead time and wastage natural resources and vision is to be a leading company in wood industry.

c) Quantification of solid wastes at CNC based wood industry- Black screen wood carving:

The quantification of wooden waste was done through field studies. It's essential to know the quantity of waste, nature of waste for understanding the efficiency of present waste management system at wood based industries. The method employed was through questionnaire and observations at site.

The quantification of waste is essential due to the following reasons. First the quantification helps to understand the quantity of solid wastes generated and quantity of wastes disposed well. Also it helps to make aware about the need of finding a method to handle solid wastes.The questionnaire and observations are two methods adopted to quantify the amount of wood wastes. The collected data was compiled by sorting of waste into in to component numbers, weighing and finally determine the weight of each type separately

Table II: Quantity of wooden wastes generated per month in industry.

Sl.No.	Items	weight
		Approximate values in kg
1	Saw dust	360
2	Chips	280
3	Cut pieces	720
4	Trimmings	90
5	Damage work	26
	Approximate total waste produced	1476

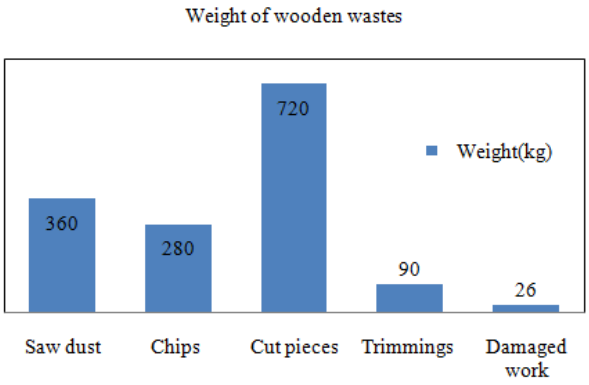

Fig 3: Total weight of individual wooden wastes at black screen wood carving

d) Wooden waste flow and disposal system in industry:

The waste flow and disposal of the present waste management system was studied in order to suggest improvement in the system. Most of the wood based industries dispose their wooden waste at their site itself and buried also some use their waste to fire up the boilers where boilers. Many others who do not have facility in their work site were disposed in road side and other places which lead environmental problems.

2.2.2 Waste collecting methods:

a) Dust collector: Dust collectors are kept near all the machines in the work station. It automatically collects dust generated during the work and immediately store to the bin provided on it. Large trimmings, cut pieces, chips are not collected by these collectors.

b) Manual collection: Workers are using broom stick collect the bigger waste like cut pieces, trimmings and chips separately and dumped in bin.

Fig 4: Dust collector

III. Methodology

3.1 Resins And Binders Used In Composite Preparation

Urea formaldehyde-based resins have been the standard binders used to glue the particles together in many composite wood products, including particleboard, wheat board, and medium density fiberboard (MDF). In recent years, however, concerns have been raising about the risks of cancer and bronchial health impacts from formaldehyde. Several market factors are driving major changes in the composition and technology of these resins. Pressure from the green building movement through market selection and certification programs, plus emissions regulations from the California Air Resources Board (CARB), are moving manufacturers to look for ways to reduce formaldehyde emissions or eliminate formaldehyde entirely from formulas.

Use of epoxy resin compared to conventional resin: Bonding wood is unlike bonding materials such as grp or metals. With wood the objective is to create joints which are stronger than the wood itself. This is not the same with other, stronger materials. The joint line in a glued metal bond, even with epoxies, is rarely stronger than the metal itself. Many types of glue create perfectly adequate waterproof joints with wood. Phenol-formaldehyde types are commonly used in the manufacture of plywood. Resorcinol and urea-formaldehyde types have been used since the 1940's to bond wooden aircraft structures with largely satisfactory results.

Whilst glues other than epoxies can form joints of adequate strength, they usually require much stricter conditions to achieve a good bond. Requirements such as good operator skill, well prepared substrate (the surface to be bonded), good workshop conditions and a service environment which does not cause them to deteriorate with age are usually necessary for a successful glued joint. Some of the most important factors are considered here:

a) Wood Moisture Level:

For many traditional wood glues, moisture content (m.c.) plays an important part in the gluing process and water is an essential requirement for the glue. The wood must therefore have the required level of moisture for the chemical reaction to take place. For phenol-formaldehyde it is 8% - 12%, for urea-formaldehyde it is 6% - 14% and for resorcinol 12% - 18%. Some of the moisture required can be gained from the glues themselves - urea-formaldehydes can generate up to 50%-60% water and phenol-formaldehydes approximately 35% water by weight. Epoxy adhesives cure by a different chemical process. They neither contain water, nor is water necessary for them to form bonds with wood. Epoxies can therefore perform very satisfactorily below 6% m.c. as well as giving excellent bonds up to 20% - 25% m.c., well outside the limits of the other glues. Kiln dried timber often has a moisture content well below 8% and is therefore best glued using epoxy adhesives.

b) Pressure Requirements During Cure:

Glues other than epoxies require the mating wood surfaces to be in close contact and under pressure. In the manufacture of plywood, both of these requirements are met since the wood veneer is compacted in giant presses using heat. Both the resorcinol and urea-formaldehyde types, which are the most common alternative glues to epoxy, require high clamping pressure in the order of 7-14 kg/m2 for an effective bond. In part this is to overcome natural surface roughness of the wood but the main reason that pressure is necessary is to counteract the shrinkage in the glue itself which occurs when the glue loses moisture as part of its curing process.Spabond 370 is prefilled and ready to use as supplied but extra filler can be added if desired/required. Fillers are in the form of powders which are added to the resin/hardener mixture. A brief guide to the types of filler available, the suitability of each, is given below. A separate Filler Guide, available from Gurit, gives full details of quantities to use, mixing methods, etc.

3.2 Eco-board/ Wooden Waste Composite Preparation

The general steps used in this process include mechanical pulping of wood chips to fibers (refining), drying, blending fibers with resin and sometimes wax, forming the resinated material into a mat, and hot pressing. Figure 5 presents a process flow diagram for a typical plant.The furnish for eco-board normally consists of wood chips. Wood chips typically are delivered from dust collector and wood waste dumping area. If necessary, the chips are washed to remove dirt and other debris.Clean chips are softened in a steam-pressurized digester, then transported into a pressurized refiner chamber. In the refiner chamber, single or double revolving disks are used to mechanically pulp the softened chips into fibers suitable for making the board. From the refiners, the fibers move to the drying and blending area. A rotary predryer may be used for initial drying of relatively wet furnish. Regardless of whether or not a predryer is used, tube dryers typically are used to reduce the moisture content of the fibers to desired levels. Single-stage or multiple-stage tube drying systems are commonly used in eco-board manufacture. Heat is usually provided to tube dryers by the direct firing of propane, natural gas, or distillate oil or by indirect heating.

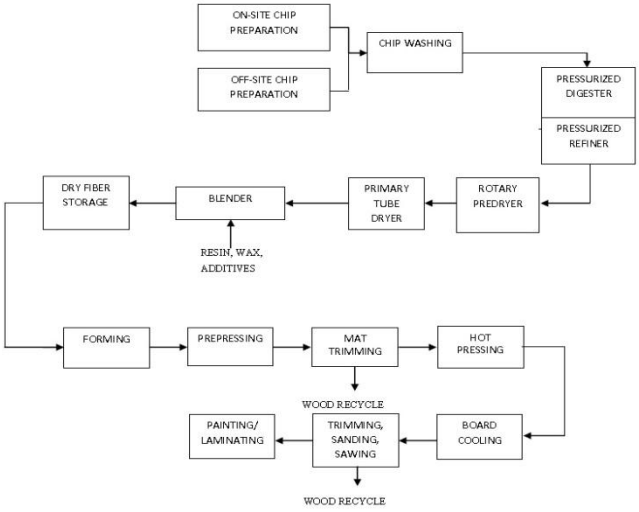

Fig 5: Flow chart

The sequence of the drying and blending operations depends on the method by which resins and other additives are blended with the fibers. If resin is added in a separate blender, the fibers are first dried and separated from the gas stream by a fiber recovery cyclone, then conveyed to the blender. The fibers then are blended with resin, wax, and any other additives and conveyed to a dry fiber storage bin. If a blowline system is used, the fibers are first blended with resin, wax, and other additives in a blowline, which is a duct that discharges the resinated fibers to the dryer. After drying, the fibers are separated from the gas stream by a fiber recovery cyclone and then conveyed to a dry fiber storage bin.Air conveys the resinated fibers from the dry storage bin to the forming machine, where they are deposited on a continuously moving screen system. The continuously formed mat must be prepressed before being loaded into the hot press. After prepressing, some pretrimming is done. The trimmed material is collected and recycled to the forming machine.

The prepressed and trimmed mats then are transferred to the hot press. The press applies heat and pressure to activate the resin and bond the fibers into a solid panel. The mat may be pressed in a continuous hot press, or the precompressed mat may be cut by a flying cutoff saw into individual mats that are then loaded into a multi-opening, batch-type hot press. After pressing, the boards are cooled, sanded, trimmed, and sawed to final dimensions. The boards may also be painted or laminated.

IV. Results And Discussions

The fabricated sheet of wood waste composite is subjected to mechanical testing in order to find its mechanical properties.

Table III: Eco-Board Technical Data

DESCRIPTION	UNIT	INDEX
Product name		Wood waste composite (Eco-board)
Product color		Light brown
Surface density kg/m3	Kg/m^3	730
Surface hardness	Shore(D)	>=48
Tensile strength	Mpa	>=47
Impact strength	kJ/m^2	>=12.44
Flexural strength	Mpa	73.73
Water absorption	%	13.4
Light transmission		Nil

Table IV: Comparative Study with wood

CHARACTERIZATIONS	WOOD	ECOBOARD
Price	Costly	Cheaper
Finishing	Need furnishing and polishing	Need finishing and polishing
Raw materials used	Natural wood	Wood pulp
Construction	Homogeneous	homogenous
Flammability	Flammable	flammable
Specialty	Aesthetic looks	Flexibility in usage
Water proofing	Not water proof	Comparatively more water repellent
Screw holding	Excellent	Excellent
Maintenance	Need polishing	Need painting
Availability	scares	Available
Wastage	Cut pieces can be used	No wastage
Durability	Subject to application	Long lasting

V. Applications

The composite prepared from the wood waste has wide range of application in modern life. Without entertaining the wood to be used in construction the use of newly introduced eco-board can play a vital role and can be used as a substitute of wood for every wood related application. The eco-board can be used with the help of mould and as well as panels which can be cut to desired sizes for the purpose to be in practice. Basically two different applications are made, which are as follows.

5.1 Preparation of mould for specific part production

5.1.1 Design of airfoil for gyrocopter(NACA 8-H-12): An autogyro also known as gyroplane, gyrocopter, or rotaplane, is a type of rotorcraft which uses an unpowered rotor in autorotation to develop lift, and an engine-powered propeller, similar to that of a fixed-wing aircraft, to provide thrust. While similar to a helicopter rotor in appearance, the autogyro's rotor must have air flowing through the rotor disc to generate rotation. An

autogyro is characterized by a free-spinning rotor that turns because of passage of air through the rotor from below. The vertical (downward) component of the total aerodynamic reaction of the rotor gives lift for the vehicle, and sustains the autogyro in the air. A separate propeller provides forward thrust, and can be placed in a tractor configuration with the engine and propeller at the front of the fuselage, or pusher configuration with the engine and propeller at the rear of the fuselage. The autogyro rotor blade generates lift in the same way as a glider's wing by changing the angle of the air as the air moves upwards and backwards relative to the rotor blade. The free-spinning blades turn by autorotation; the rotor blades are angled so that they not only give lift, but the angle of the blades causes the lift to accelerate the blades' rotation rate, until the rotor turns at a stable speed with the drag and thrust forces in balance. Because the craft must be moving forward (with respect to the surrounding air) in order to force air through the overhead rotor, autogyros are generally not capable of vertical takeoff or landing (unless in a strong headwind).

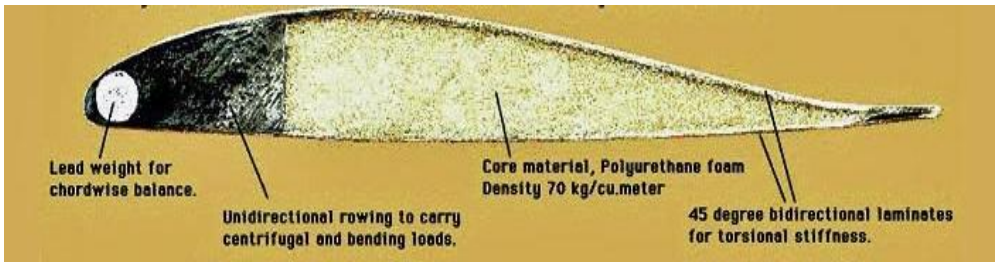

Fig 6: cross section of NACA 8-H-12 airfoil

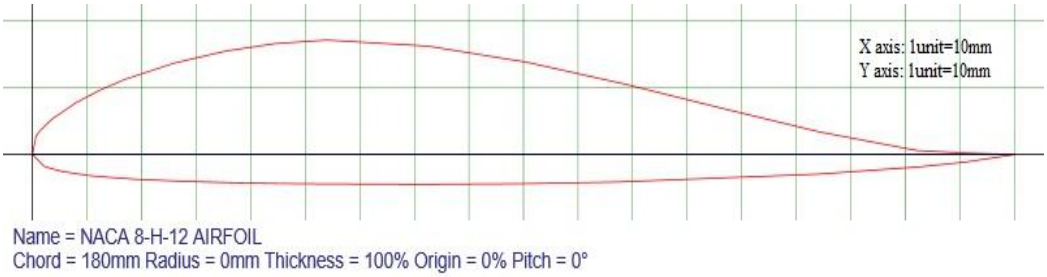

Fig 7: Airfoil plot

5.1.2 ACA airfoil details:

The early NACA airfoil series, the 4-digit, 5-digit, and modified 4-/5-digit, were generated using analytical equations that describe the camber (curvature) of the mean-line (geometric centre line) of the airfoil section as well as the section's thickness distribution along the length of the airfoil. Later families, including the 6-Series, are more complicated shapes derived using theoretical rather than geometrical methods. Before the National Advisory Committee for Aeronautics (NACA) developed these series, airfoil design was rather arbitrary with nothing to guide the designer except past experience with known shapes and experimentation with modifications to those shapes.

a) NACA Four-Digit Series: The first family of airfoils designed using this approach became known as the NACA Four-Digit Series. The first digit specifies the maximum camber in percentage of the chord (airfoil length), the second indicates the position of the maximum camber in tenths of chord, and the last two numbers provide the maximum thickness of the airfoil in percentage of chord. For example, the NACA 2415 airfoil has a maximum thickness of 15% with a camber of 2% located 40% back from the airfoil leading edge.

b) Advantages:

- Good stall characteristics
- Small center of pressure movement across large speed range
- Roughness has little effect

c) Disadvantages:

- Low maximum lift coefficient
- Relatively high drag
- High pitching moment

d) Applications:

- General aviation
- Horizontal tails

Symmetrical:

- Gyrocopter
- Helicopter blades
- Shrouds

5.1.3 Preparation:

The airfoil NACA8 H 12 is the airfoil used for gyrocopter manufacturing. Mainly it comes in the dimension of 3250x180x21 mm^3. In order to make a mould of this rub-wood of 25mm thickness and 2440x1220mm^2 dimension is used. The software platform used to prepare mould is Art CAM 7000 from which mould design along with the tool path with a suitable tool can be generated in a precise manner. Since the rub-wood sheet comes with 2440x1220 mm^2 the sheet was cut down to get the desired length of airfoil. With the use of CNC router machine available in the industry the mould has prepared with male and female parts. When these two pieces are combined together the exact shape of mould of the airfoil can be generated.

Fig 8: Design prepared on Art Cam software

The machined rub-wood with the mould were joined together. A metal frame with a dimension of 3270x280x41 mm^3 was also prepared to make the rub-wood mould to be rigid to apply compression after the mixture been prepared. The rub-wood dye is fixed with the metal frame with the help of same composite pulp.

Fig 9: Mixing mould with metallic frame

Fig 10: Filling airfoil mould with composite mixture

Fig 11: fastening male and female parts for curing

A bronze rod of 10mm diameter and 3200mm length is used as a reinforced in the mould. Unidirectional waived fibre glass mesh is used to increase the tensile strength of the airfoil. After the application of the mould mixture which comprises of the wood flour, epoxy resin along with the suitable hardener. Before applying the mixture to male and female part the rub-wood mould is coated with the wax in order to make the dismantling of the mould after completion smoothly. After the completion of all these process the male and female part is fastened with nuts and bolts and allowed it to be get settled for three days.

5.2 Machining in the CNC router machine

Wood composite should have a machinenability property as like wood in order to use it as a substitute for wood. In order to check that property the panel board prepared from the wood waste has been tested in CNC router machine to check its performance and finish in the machine. The programme will be done on the machine with desired tool and other parameters. This provided a smooth surface finished along with a clear design carved in the eco-board as like the carving has been done on the teak wood.

Fig 12: Roof of temple machined using eco-board

Fig 13: Readymade paneling board in MDF

VI. Conclusion

This study has developed concepts for the reutilization of construction materials, including waste debris, by means of recycling into other components that are useful in construction. Utilization of existing resources in the best manner is major challenges in the sustainable developments. Most of the composite has less life with its usage and have very low surface finish. At the same time the cost for production should also be less as compared to wood. Most of the wood industries are facing a major problem with the saw dust and cut pieces of wood. Many of them uses it to supply for hotels for cooking purposes and some others dump their waste at isolated landfills and thus producing environmental problems.Here the CNC router waste in the wood industry is used for recycling it with epoxy resin and hardener to prepare an airfoil within its desired specification. It was observed to be a solid rigid blade that can be used in real gyrocopter with a low cost.

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