1. **INTRODUCTION**

**WOOD NATURE’S BEST BUILDING MATERIAL**

Wood is one of the few natural products that man has used throughout history without having to modify its properties. In recent years, however, several treatments have been developed to modify wood for special applications. For example, Impreg, the commercial term for wood treated with water-soluble polymers, is often used for electrical control equipment because of its electrical resistance. There are few treatments that alter the physical properties of wood and thus affect its strength stability & stiffness out of that one is liquid monomers that polymerize in the lumen of wood cells (methyl methacrylate, epoxy resin);

Wood is a natural composite of cellulose and lignin. Cellulose fibres are strong in tension and lignin cements these fibers together to give them stiffness. Wood displays a wide spectrum of technological and domestic applications. The physical and mechanical properties of wood are largely related to their bulk structure. It is no exaggeration that wood is only a natural resource catering the needs of society as a source material for construction, chemicals, fibers, pulp & paper etc., since long time. Wood
finds many engineering applications and has long been a common
construction material. The advantages of wood over other materials are
that wood is strongest of the cellular materials and the cheapest; easily
available in large quantities, easy to process & join, has light weight,
easy to obtain good surface finish, inexpensive, easy to repair & its
inherent beauty.

Wood, a renewable resource, provides tools, weapons, and shelter.
Since prehistoric times, human have learned how to make wood harder
and stronger by drying and heat tempering wooden tools and weapons.
Later other modifications have been attempted to better fit its increased
requirements. High affinity of wood for moisture is an important factor in
controlling its dimensional stability. Over the years, tars, pitches,
creosote, resins, and salts have been used to coat wood or to fill its
porous structure to enhance its dimensional stability (Mayer, 1981).

The performance of wood as a construction material for outdoor
applications deteriorates under accelerated weather environments due to
fluctuations in temperature and humidity. For prolonged outdoor
applications as well as decreasing the ultimate cost of wood and avoiding
the need of frequent replacements in permanent and semi permanent
constructions, a number of wood preservatives and new wood treatment
processes were developed since past few decades. Those wood treatment processes are under continuous demands which could develop the modified wood materials with improved mechanical strength, thermo-oxidative stability, resistances towards biodeterioration and solvents for their better outdoor applications (Schneider et al., 2000 Clemons, 2002)

Wood-plastics composites WPC are a new group of materials that are generating interest in both the UK and overseas. The term 'WPC' covers an extremely wide range of composite materials using plastics ranging from polypropylene to PVC and binders/fillers ranging from wood flour to flax. These new materials extend the current concept of 'wood composites' from the traditional compressed materials such as particle-board and medium density fiberboard MDF into new areas and, more importantly, a new generation of high performance products.

The first generation of 'wood composites' were a combination of recycled wood flour or chips and binders. These were ideal for relatively undemanding applications. The new and rapidly developing generation of WPC 'wood composites' have good mechanical properties, high dimensional stability and can be used to produce complex shapes. They are tough, stable and can be extruded to high dimensional tolerances. The
new WPC materials are high technology products for the most demanding applications.

The most common types of the new WPCs are produced by mixing wood flour and plastics to produce a material that can be processed just like a plastic but has the best features of wood and plastics.

The wood can be from sawdust and scrap wood products. This means that no additional wood resources are depleted in WPCs. Waste products that is currently cost money for disposal are now a valuable resource - recycling can be both profitable and ethical. The plastic can be from recycled plastic bags and recycled battery case materials although in demanding applications new plastics materials are used. The recycling ethos is to use materials recovered from short life cycle applications in long life cycle applications.

WPCs are wood products that need no further processing. WPCs are weather, water and mould resistant for outdoor applications where untreated timber products are unsuitable. WPCs are plastic products with exceptional environmental credential and performance.
WPCs are made using a variety of raw materials. The basic wood and plastic mix must be modified with process and property additive to improve processing or the final properties of the WPC.

WPCs have a wide range of applications. They can cost-effectively replace wood products in applications such as furniture, door frames, decorative profiles, in fact anywhere wood shapes are used. They can cost-effectively replace plastic products in applications such as window, frames, cable trunking, roofline products and cladding, in fact anywhere that plastics shapes are used.

WPCs have many benefits: They are true hybrid materials and combine the best properties of both wood and plastics. They use low cost and plentiful raw materials. Wood waste and recycled plastics become assets instead of liabilities. They are competitively priced and are competitive with traditional materials such as timber and PVC-U. They are easily produced and easily fabricated using traditional wood processing techniques. They are available in a broad range of finishes and appearances. They are easily recycled after use.

One of the major concerns with WPCs in the past has been the difficulty in combining plastics intimately with the wood flour. The
general technique is to use a compatibiliser or coupling agent to improve the blending of the two materials.

WPCs can be processed using conventional wood working tools and has similar to wood or MDF. The uniform density of the products even makes processing easier than with traditional wood products and the net shape extrusion means that many normal processes are not needed.

WPCs can be cut finished and fastened just like wood. A major benefit of extruded WPCs is that the final products form can be produced in a single step. For the first time accurate shapes are available for wood products. This is timber without the waste. The fine control on profile dimensions also means improved products performance and reduced materials usage.

Net shape profile production allows products to be designed with stiffening legs, internal hooks, internal dividers, snap fittings and internal strengthening walls - all the features of plastic profile design but in wood. This means profile weight (and cost) can be reduced and reduced material content also helps profile cooling to increase production speeds.

Profiles can be designed with connectors to allow product systems to be developed - a concept previously not possible with wood products.
WPCs represent a new era of materials development that combines the old with the new to deliver an exciting new option for the end user. The range of materials being developed is wide and exciting and progress is rapid. The new WPC materials cover a wide range of polymer matrix types as well as a wide range of fillers and stiffeners.

WPC materials reduce costs, increase production rates and offer a wide range of benefits to the end user.

One of the virtuous areas is that the more wood flour that is added, the lower the price of the raw material and also the higher the stiffness of the raw material. Lowering the cost can actually improve the performance.

Designers can add previously unobtainable value to wood products by using precisely formed products with internal hollows, strengthening ribs and re-entrant angles. The possibilities of wood products can be expanded to use all of the advantages of plastics processing.

Current applications for WPCs are largely in finished products such as decking, cladding and window frames. In the USA, the market for WPC products has grown at a rate of 100% per year for the last 5 years and this is increasing as new applications are found for the
materials. A particular growth area is in structural engineering applications that use the physical properties of WPC to the limits.

WPCs can be used for products traditionally manufactured from timber and PVC-U and typical applications are:

- Planking and pre-finished floorboards
- Stairs and hand rails
- Window frames and components
- Garden furniture and architecture,
- Kitchen cabinets and worktops
- Exterior vertical and horizontal
- Decking, docks and railings
- Dado rails, Skirting boards
- Doorframes and components
- Balustrades
- Shelving
- Office furniture
- Cable trunking
- Fencing and fence posts.
WPCs are only slowly gaining acceptance in the UK, despite huge commercial success in the USA. Despite research into this area since 1990 the UK plastics industry has largely ignored the development of WPCs. UK plastics processors could well be missing the start of the next generation of materials.

One of the few UK companies active in this area is Timbaplus products. It is good to see at least one UK company starting to work in this exciting area. The future for WPCs is bright and also it appears that the users will recognize the benefits before the manufacturers.

Fiber reinforced polymer composites began with cellulose fiber in phenolics in 1908, later extending to urea and reaching commodity status in the 1940s with glass fiber in unsaturated polyesters. From guitars, tennis racquets and cars to micro light aircrafts, electronic components and artificial joints, composites are finding use in diverse fields. Because of increasing environmental consciousness and demands of legislative authorities, the manufacture, use and removal of traditional composite structures, usually glass, carbon or aramid fibers being reinforced with epoxy, unsaturated polyester resins, polyurethane’s or phenolics, are considered critically. The most important disadvantages of such composite materials is the problem of convenient removal after end of
life time, as the components are closely interconnected, relatively stable and therefore difficult to separate and recycle Government regulations and growing environmental awareness throughout the world have triggered a paradigm shift towards designing materials compatible with the environment. The natural and wood fibers derived from annual renewable resources, as reinforcing fibers in both thermoplastic and thermosets matrix composites provide positive environmental benefits with respect to ultimate disposability and raw material utilization.

The developments of artificial fibers like carbon and glass, it is remarkable that natural grown fibers have gained a renewed interest, especially as a glass fiber substitute in automotive industries. Fibers like jute, wood, flax, coir or hemp are cheap, have better stiffness per unit weight and have a lower impact on the environment. Although automotive take the lead in the revival of natural fibers, applications are mainly restricted to upholstery applications where acoustic and thermal insulation, low cost and a environmental image are advantages.

The natural fiber consumption in the automotive industry in Europe which was 21300 ton in 1999 and 28300 ton is in the year 2000 shows the rapid increasing of natural fiber consumption. It was also reported that wood polymer composites account for a 300.000t/year
market in USA for building and garden products and should more than double by 2005. Decking accounts for about 60% of the total and rest of for flooring etc. And natural fiber composites of thermoplastics and thermo sets are shortly to be approved by the US Federal Aviation Authority and the UK Civil Aviation Authority for aerospace applications.

There is a renewed interest in the use of natural fibers, which are also known as agro-based resources for composites. These resources include wood, agriculture plants and residues, grasses, water plants, and a wide variety of waste agro-mass including recycled wood, paper, and paper products.

Jute is one of the most common agro-fibers having better mechanical properties which is sometimes superior to glass fibers. The price for natural and wood fibers which are feasible for different applications varies a lot depending on the changed economy of the countries where such fibers are widely available. Jute is the so-called golden fiber from Bangladesh. Diversified uses of jute are therefore now essential to enable the jute industry to survive, and new outlets for the fiber are being sought in wider textile fields and other engineering
applications beyond wrapping and packaging. This technology recognized as Tangram Technology in 2002.

During the early 1960s new classes of chemicals containing one or more double bonds were used to treat wood. The chemicals consisted of vinyl type monomers that could be polymerized into solid polymers by means of free radical of mechanism.

As the theory of Balatinecz and Woodhams in 1993. The polymer loading of wood 'depends on the permeability of the wood species being treated. Because the void volume is approximately the same for sap wood and heartwood for each species. It would be expected that the polymer would fill them to same extent.

The permeability of wood is measured using either a liquid or a gas, but a gas is more convenient. Permeability measurements using liquids are complicated by entrapped air in small openings. Owing to low viscosity, rate of flow of a gas is much greater than that of a liquid.

The permeability of wood to gases has been investigated by several researchers and generally agrees on the complexity of the mechanism of fluid flow through difficult-to-treat hardwoods. Research workers like Comstock (1968) and Siau (1969) have developed satisfactory techniques
for measuring permeability to understand the mechanism of flow through capillaries of wood the permeability of wood species is one factor that how easily it can be dried and treated. Wood exhibiting high permeability is easy to dry and treat; and that with low permeability is not easy to dry and treat (Milota, et al., 1995). Permeability is reduced if the pits are encrusted, occluded, or aspirated or if the vessels in hardwoods are plugged with taluses, Kemp (1957) found that permeability in sapwood is distinctly greater than in hardwood due to plugging of vessels by taluses.

A number of investigators have studied the influence of steaming on drying time and permeability of wood. Ellwood and Erickson in 1962 studied the influence of steaming and found that pre-steaming the wood for 4 hours could substantially reduce the drying time of redwood. Ellwood and Ecklund in 1961 reported that permeability of redwood and black oak could be improved by steaming. Benvenuti in 1963 observed that the permeability of loblolly pine sapwood was 30 times more after steaming the green wood at atmospheric pressure for 4 hours. Pre-steaming also improved the drying rate in refractory woods (Mackay, 1971; Kozlic et al., in 1972. Steaming reportedly improves the radial permeability of some pine species, possibly by breaking down components that block flow through ray tissues (Vinden et al., 1985).
Although, it is known that steaming improves the permeability of a number of species. Comstock (1965) has suggested the possibility that steaming does not actually increase permeability, but merely causes the wood to retain its green permeability after drying; Erickson and Crawford (1959) also observed that steaming had no appreciable effect on the permeability of green sapwood, but that steamed sapwood retained a much higher permeability after drying than sapwood which was non-steamed.

It was considered desirable to study the permeability of plantation grown Acacia nilotica, a timber that is grown largely in arid and semi-arid regions under forestation programmed to fulfill the socio-economic needs of fuel, fodder and timber. As a timber it finds utility in rural sector for agricultural implements and other structural materials.

With the advancement of polymers and plastics, scientist could employ yet another group of chemicals to coat and treat the ancient raw material wood. During World War II, phenol-formaldehyde resin, based on research work of the forest service, forest products laboratory U.S.A. was used to treat wood veneer and formed the composite for aero plane propellers.
Commercial production of wood polymer composites (WPCs) began in the mid 1960s, using the radiation process." In the late 1980s, the catalyst heat process has been widely used for making wood-polymer composites, but in smaller volume than the radiation process. Because of the simplicity of the catalyst-heat process and the low capital investment, the products are used by small companies that make high cost, low volume articles.

The government of the United Kingdom, Finland, Sweden, West Germany, South Africa and others support the radiation process for making WPCs through catalyst heat system is generally used. A research group at the, University of New Brunswick, Canada, is assisting industry in setting up the catalyst-heat process to produce knife handles and other articles. In Poland and China large production facilities were constructed for making styrene-wood polymer composites called igniters by the catalyst heat process. The Japanese have been very active in research and production of wood-polymer composites using the catalyst-heat system with MMA and styrene mixtures. The Japanese products include pen and pencil sets, office equipments, wall panels and flooring under the trade name of Aploid. In Taiwan and number of wood-polymer composite products are made with mixtures of styrene-polyester, MMA-styrene and
MMA-polyester as the monomers in the catalyst-heat process. Some WPCs are made in Australia and New Zealand.

When wood polymer composites were introduced 40 years ago, it was predicted that this process would solve the problem of dimensional stability of wood; great claims were made for its future use. Today the physical properties of WPCs are better understood and specific commercial products are taking advantage of the desirable appearance, high compression strength, static bending strength, wear strength, increased hardness and abrasion resistance and improved dimensional stability.

Literature survey indicated that, although the performances of wide varieties of low grade woods were improved through impregnation of Polyacrylonitrile PAN. Still no significant efforts were made to impregnate this polymer into Eucalyptus, Poplar and Babool wood through both of the catalyst heat and radiation induced curing process.

The requirement of Eucalyptus, Poplar and Babool wood as a construction material demand its substantial dimensional stability. These medium soft woods although offer a wide spectrum of applications as a construction material, yet is affected by moisture, heat and high load.
Therefore for prolonged durability and better services, the wood still require improved dimensional stability and thermal stability. Such demerits of above said low grade woods could be reduced by appropriate thermoplastic reinforcements into its bulk that may not only impart dimensional and thermal stabilities but also resistance towards environmental decay of these woods. In the present work efforts have been made to develop Polyacrylonitrile PAN reinforcement in Eucalyptus, Poplar and Babool wood at a varying concentration of Acrylonitrile monomer through heat curing process using benzoyl peroxide as catalyst in view to enhance its dimensional-stability. The impregnation process has been executed at three different concentrations of monomer in view to get the clear understanding about the saturation limit of monomer into woods and related property changes involved in composites. The properties of wood have been evaluated as:

1. Compression strength
2. Impact Strength
3. Wear strength
4. Thermal stability
5. Wood polymer compatibility through scanning electron micrographs
6. Statistical analysis

Since woods are mostly used as construction materials in the form of panels, particle boards, ply boards that require heat processing under load in oxidative conditions, for the fabrication into the desired articles. Therefore, thermal analysis of the prepared composites has also been made in view to ascertain their thermal stability. Such combinations of mechanical and thermal properties of the composites may provide better information in the area of plywood industry. Polyacrylonitrile PAN reinforcement in wood has performed by using benzoyl peroxide as a catalyst. Such catalytic process has generated free radicals that have induced polymerization of acrylonitrile trapped in wood voids into Polyacrylonitrile PAN at a great economical value. As this free radical method does not require any curing by oven or any other costly source like gamma radiation. Salient features of such catalyst based monomer reinforcement into wood are as follows:

(1) Chemicals involved are easy to handle

(2) No such costly oven or gamma induced curing methods are involved

(3) Reinforcement can be performed under environmental conditions without using any costly equipment
(4) The process is having no pollution hence environmentally friendly that produce eco-friendly composites.

The mechanical properties of wood are largely related to its bulk structure. Common mechanical characterizations of woods are usually performed on universal testing machine. The significance of the data collected can also analyzed statistically by t-test. Other mechanical property of wear as design parameters for applications of wood structure the wear testing is performed on the machine which indicates the wear properties of wood for different applications of wood as wear resistant material.

A qualitative relationship between the mechanism of thermo-oxidation degradation of WPCs and target woods has also been investigated using TG data. The oxidation and crystallization temperatures of woods and WPCs were deduced from DTA and the maximum and final decomposition temperature were deduced from DTG respectively.

The polymer wood affinity can be seen by using the electron micrographs of wood and its WPCs. The scanning help to study the extent of polymer loading and its variations in the thickness of wood
voids. The comparison of the various scanning electron micrographs of wood with its various WPCs.

In the present research work efforts are to develop the composites of having improved mechanical and thermal stabilities with less wear volume. So that these can be utilized commercially for the desired purposes. The detailed literature review is being described in Chapter 2.