Sustainable Building Materials in Kerala – An Overview

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Abstract— **Kerala, God's own country is blessed with immense natural resources. It's high time that the state's natural resources being utilized effectively. While sustainable development is the need of the hour, we have to take lead in initiating activities that would minimize the exploitation of our natural resources resulting in their effective utilization. This paper narrates an overview of innovative building materials especially using natural fibres available in Kerala and discusses the feasibility of utilising such fibres in the context of sustainable building materials in Kerala. The paper also discusses how these materials can be effectively utilized to reduce the huge investment in the construction industry.**

Index Terms— **coir, straw, pineapple leaf fibre, off-white rice husk, cotton fibre, tapioca stalk**

I. Introduction

Sustainable development is often an over-used word, but goes to the heart of tackling a number of inter-related global issues such as poverty, inequality, hunger and environmental degradation. Sustainable building materials include rapidly renewable plant materials like bamboo (because bamboo grows quickly) and straw, lumber from forests certified to be sustainably managed, ecology blocks, recycled stone, recycled metal, and other products that are non-toxic, reusable, renewable, and/or recyclable) The EPA (Environmental Protection Agency) also suggests using recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects. Building materials should be extracted and manufactured locally to the building site to minimize the energy embedded in their transportation.

Natural fiber composites, or biocomposites, have recently gained much attention due to their low cost, environmental friendliness, and their potential to compete with glass-fiber composites. Study report demonstrates that biocomposites can be used for load-bearing components by improving their structural efficiency through cellular material arrangements. Laboratory-scale periodic cellular beams and plates were made from industrial hemp and flax fibers with unsaturated polyester resin. Material and structural performance was experimentally assessed and compared with results from short-fiber composite micro-mechanics models and sandwich analyses. Short-term analytical evaluation of full-scale cellular biocomposite components indicates that they can compete with components made from conventional materials [1]. Lignocellulosic agricultural byproducts are a copious and cheap source for cellulose fibers. Agro-based biofibers have the composition, properties and structure that make them suitable for uses such as composite, textile, pulp and paper manufacture. In addition, biofibers can also be used to produce fuel, chemicals, enzymes and food. Byproducts produced from the cultivation of corn, wheat, rice, sorghum, barley, sugarcane, pineapple, banana and coconut are the major sources of agro-based biofibers suitable for various industrial applications [2].

In Kerala, we are blessed with lush green paddy fields, coconut palms, plantains, tapioca, pineapple and cotton from which we can extract rice husk, straw, coconut husk, banana fibre, tapioca stalks, pineapple leaf fibre and cotton fibre respectively. All the above natural fibres form part of sustainable building materials. Coir pith from coconut husk is often piled up as a waste material creating lot of environment problems within the state. Studies have shown that coir fibre reinforced cement can be used as a low cost roofing material.

II. Background Study

For past few years, several studies have been conducted in the area of sustainable building materials. Most of the countries have switched over to the locally available sustainable building materials in their area for their construction industry thereby making their environment eco friendly. In a project, sponsored by the National Science Foundation, to develop bio-based composite materials for the next generation of American housing panel applications, a group of researchers at Michigan State University strived to generate eco-friendly greener composite materials for structural applications. The objective of the research was to determine if bio-composites designed and engineered from natural/bio-fibers and blends of polyester resin and derivitized soybean provide environmental gains, reduced energy consumption, lighter weight, insulation and sound absorption properties, elimination of health hazards and reduce dependence on petroleum based and forest product based materials. A three cornered approach including the use of engineered natural fibers, polymer resin modification and development of a new high volume continuous manufacturing processes(Bio-Composite Sheet Molding Compound Panel-BCSMCP) was required to achieve the

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objective of producing an affordable alternative construction material for the housing industry of the 21st century [3].

At the Central Building Research Institute, Roorkee, the potential of sisal and jute fibres as reinforcements have been systematically investigated to overcome their well-defined problems of moisture absorption. The performance of polymer composites made from these natural fibres and unsaturated polyester/epoxy resin was evaluated under various humidity, hygrothermal and weathering conditions. Consequent to this, various composite products such as laminates or panels, doors, roofing sheets, shuttering and dough moulding compound have been prepared. The suitability to these products is assessed as an alternate material according to the existing Indian standard specifications. The process know-how for the manufacturing of natural fibre composite panels or door shutters has also been commercialized [4].

Aggarwal, L.K. **(**1991) described a process for production of coir fiber reinforced cement panels. These newly developed composite panels have bending strengths of 9 to 11 MPa and modulus of elasticity of 2,500 to 2,800 MPa, and show thickness swelling of less than 1.2 percent and water absorption of 14 to 16 percent when tested with standard procedures. The panels show better dimensional stability and behavior towards fire when compared with traditional materials such as plywood, wood particleboard, and wood fiberboard and can be used as an alternative to these materials [5].

Bagasse is abundantly available in many countries as a by-product from sugar mills and is being mostly used as fuel or disposed of by incineration. Attempts have been made to convert this byproduct into useful eco-friendly cement-bonded composites, which can be used for various internal and external applications in buildings. Studies show that the developed composites meet most of the requirements of various standards on cement-bonded particle boards and have high levels of performance even in moist conditions. Therefore, in countries where bagasse is substantially available, it can be used for the production of cement-bonded building materials.

The alternative use of three Jamaican natural cellulosic fibres for the design and manufacturing of composite materials has been studied. The natural cellulosic fibres under investigation were bagasse from sugar cane (saccharum officinarum), banana trunk from the banana plant (family Musacae, genus Musa X para disiaca L), and coconut coir from the coconut husk (family Palm, genus coco nucifera). Fibre samples were subjected to standardized characterization tests such as ash and carbon content, water absorption, moisture content, tensile strength, elemental analysis and chemical analysis. The banana fibre exhibited the highest ash, carbon and cellulose content, hardness and tensile coir and bagasse fibres as composite materials [6].

III. Natural Fibre Composite Building Materials Available In Kerala

Natural fibres are low-cost, locally available in abundance and obtained from renewable resources. There is a growing interest in the development of new materials which enhance optimal utilization of natural resources, and particularly, of renewable resources. In Kerala, the available natural fibres are coir fibre, pineapple leaf fibre, banana fibre, cotton fibre, rice husk and straw and tapioca stalks.

A. Coir Fibre

Kerala is rich with coconut trees. The coconut husk is abundantly available as cheap residue from coconut production in many areas, which is known to yield the coarse coir fibre. A simple and efficient technology has been developed to produce high strength-high density board materials from whole coconut husks, without the addition of chemical binders. The board exhibits excellent properties, which are comparable with or even superior to commercial wood based panels. The pressed coconut husk boards can be handled with common wood working equipment for drilling and sawing, planning and polishing.

Chemical composition modification and surface modification of coir fibers are made in view of their use as reinforcement in coir-based green composites. Composites were prepared using coir fiber treated with varying pretreatment condition. It is observed that the mechanical properties of coir-based green composites; modulus of rupture and internal bond, increase as a result of chemical composition modification and surface modification [8]. Studies show that when compared with jute and kenaf composites, coir fibre composites displayed the lowest mechanical properties, but their impact strength was higher than that of jute and kenaf composites [9].

A study on the use of coir fibre for the production of cement-bonded building boards revealed the following facts. The investigation included the optimization of parameters such as fibre content, fibre length, casting pressure and demoulding time for the production of coir fibre-cement boards and the method of their production. The bond strength between coir fibre and cement was also determined. The boards were produced by using the parameters finalized as above and their physico-mechanical, thermal and fire properties were determined. The results obtained from these studies showed that the developed boards meet the requirements of various standards on cement-bonded particle boards. Therefore, it is feasible to use coir fibre for producing building boards in countries where this fibre is readily available [10].

The water absorption and swelling characteristics along the surface and thickness were determined for particle boards made from coir pith of 0.4, 0.8, 1.2 and 2.1 mm average particle sizes using phenol–formaldehyde and urea–formaldehyde resins. The water absorption and swelling were least for the board made from largest-size particles and phenol–formaldehyde resin [11].

Referring to the above studies its is clear that Kerala has immense scope in using coir fibre as natural composites for the construction industry.

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B. Pineapple Leaf Fibre

Pineapple leaf fibre, which is rich in cellulose, relative inexpensive and abundantly available has the potential for polymer-reinforced composite. A study investigated the tensile and flexural behaviours of pineapple leaf fibre–polypropylene composites as a function of volume fraction. The tensile modulus and tensile strength of the composites were found to be increasing with fibre content in accordance with the rule of mixtures. The tensile modulus and tensile strength with a volume fraction 10.8% are 687.02 MPa and 37.28 MPa, respectively. The flexural modulus gives higher value at 2.7% volume fraction. The flexural strength of the composites containing 5.4% volume fraction was found to be higher than that of pure polypropylene resin by 5.1%. Scanning electron microscopic studies were carried out to understand the fibre–matrix adhesion and fibre breakage [12].

C. Cotton Fiber

Cotton is cultivated primarily for its fiber; little use is made of the plant stalk. Stalk harvest yields tend to be low and storage can be a problem. The cotton stalks may be plagued with parasites, and stored stalks can be a dwelling place for the parasites. If the parasite issue can be addressed, cotton stalks can be an excellent source of fiber. Cotton stalk fiber is found to possess the structure and dimensions similar to common species of hardwood fiber.

Kerala is also blessed with adequate cotton trees. Studies were also conducted on the feasibility of using cotton fibre as natural fibre composites. It was found that with the addition of 10 wt% cotton fiber, the tensile strength decreases, but with the addition of 20 and 30 wt% cotton fiber it increases because of the entanglement of the cotton fibers [13].

D. Banana Fibres

Banana plant waste, as lignocellulosic fiber, was treated with alkaline pulping and steam explosion to produce banana fibers and banana micro fibrils. The chemical composition of the ensuing fibers and micro fibrils was determined. Better compatibility and enhanced mechanical properties were obtained when using banana micro fibrils. The chemical composition of fibers, in terms of lignin and cellulose, as well as their degree of crystallinity, were found to have a strong influence on the mechanical properties of the composites [14].

Musacea bunch was pretreated and used to produce fiberboard with non-synthetic binders. The lignocellulosic material was steam exploded with a thermo mechanical aqueous vapor process in a batch reactor. The effect of the pretreatment and the pressure conditions on the physical–mechanical responses of the fiberboard was evaluated and the conditions maximizing the responses were found. Response surface methodology with a central composite design was used. The variables studied and their respective variation ranges were: pretreatment severity, 3.16–4.84; pressing temperature, 133–217 °C; pressing pressure, 3.95–14.04 MPa.

The fiberboards obtained were good quality and satisfied the requirements of the relevant standard specifications.The effect of the pretreatment severity on the lignin, cellulose and xylans content was also determined by an analysis of variance. The decrease in xylans was clearly related to the increase in the dimensional stability of the fiberboards [15].

E. Rice Straw and Husk

Rice husks, an agricultural residue are available in fairly large quantities in Kerala. Rice husks are quite fibrous by nature and require little energy input to prepare the husks for board manufacture. To make high quality boards, the inner and outer husks are separated and the husks are broken at their "spine" Resin is applied, then the rice husk particles are air laid like any other lignocellulosic material. Large amounts of rice husk ash (RHA) are produced every year worldwide and difficulties related to their disposal may cause this product to become an environmental hazard.

Rice husk ash, one of the promising pozzolanic materials that can be blended with Portland cement for the production of durable concrete and at the same time it is a value added product. Addition of rice husk ash to Portland cement not only improves the early strength of concrete, but also forms a calcium silicate hydrate (CSH) gel around the cement particles which is highly dense and less porous. This may increase the strength of concrete against cracking [16]

Recent studies have shown that the partial replacement of cement by ultra fine rice husk ash resulted in improved compressive strength and workability of concrete but decreased its water permeability. In addition, decreasing rice husk ash average particle size provided a positive effect on the compressive strength and water permeability of hardened concrete but indicated adverse effect on the workability of fresh concrete. [17]

The utilization of rice husk ash as a viscosity modifying agent (VMA) in self compacting concrete (SCC) has gained importance nowadays. The use of chemical viscosity modifying admixtures increased the expense of SCC. Researches have proved that it is feasible to develop low cost SCC by using rice husk ash as the VMA without compromising on the compressive strength of concrete. [18]

Rice straw can be used to supplement part of the fiber content in particleboard. Unprocessed baled straw is being used to build homes in most of the countries. One primary benefit claimed for straw bale building systems is that extremely high insulation values can be obtained. It has also been reported that tightly compacted straw bales are fire resistant, due to dense packing. In addition, high silica content in straw is said to impede fire because as burning begins, a layer of char develops, thus insulating the inner straw. Building codes in the United States have approved straw-bale construction on a case-by case basis, usually under the "Alternative Materials and Methods" section of the relevant building codes. The quality of the straw is highest when the grain is at its optimum ripeness for harvesting.

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Based on the above studies, our state can confidently emerge as the top user of rice husk and straw as building materials by sticking to the quality of these materials.

F. Tapioca Stalks

Tapioca contributes to one of the major crops cultivated in Kerala. Experiments carried out in Tropical Products Institute TPI).London, England using 455.8 kg of91.44-cm-long and 2.54-cm-diameter tapioca stalks showed the following results. Splinters were produced under controlled conditions, mixed with urea-formaldehyde resin in a rotary mixer, cold pressed, and then hot pressed. The standard panel was compared to British Standard 2604 for bending and tensile strengths. Results using 6, 8, and 10 percent resin were tabulated. It was determined that satisfactory board, exceeding the British Standard, can be made with 8 percent resin content, resulting in 0.64 g/cm^3 board density [19] .

The above study reveals that there is ample scope for our state to exploit its massive production of tapioca.

IV. Summary

Possibilities for the industrial utilisation of waste from fibre crops such as coconut, cotton, rice, tapioca and of fibre waste from fruit plants such as banana and pineapple are described. Investigations on the industrial use of banana fibre and pineapple leaf fibre, fibrous wastes from fruit plantations, are outlined. Future studies are required to be conducted on the prospects of using tapioca fibre as a natural fibre composite. Detailed exploration and research in the effective utilization of the above mentioned natural fibres would result in economical improvement and eco friendly environment generation for the state of Kerala. Studies reveal that we have to put in lot of effort in efficiently utilizing our own locally available sustainable building materials for shaping our own economy to the fullest extent.

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