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compilation of seminar papers

Compilation Of Seminar Papers

Potentiality of coir for salient application

Research finding By

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Abstract

1.0 Introduction

Coir is a natural fiber gifted by god to us. Coir fiber is extracted from the outer layer (husk) of the fruit of coconut tree Cocos Nucifera L. The coconut husk consists of a smooth waterproof outer skin (epicarp) and fibrous zone (mesocarp). The mesocarp comprises fiber strands of coir embedded in a non fibrous "cork-like" connective tissue usually referred to as pith. The pith ultimately becomes coir dust.

Coir fibers recovered from fully ripened coconuts yield brown coir. Strong and highly resistant to abrasion, its method of processing also protects it from the damaging ultraviolet component of sunlight. Dark brown in color, it is used primarily in brushes, floor mats, and upholstery padding.

White coir comes from the husks of coconuts harvested shortly before they ripen. Actually light brown or white in color, this fiber is softer and less strong than brown coir. It is usually spun into yarn, which may be woven into mats or twisted into twine or rope.

Both brown and white coir consist of fibers ranging in length from 4-12 in (10-30 cm). Those that are at least 8" (20 cm) long are called bristle fiber. Shorter fibers, which are also finer in texture, are called mattress fiber. A 10-oz (300-g) coconut husk yields about 3 oz (80 g) of fiber, one-third of which is bristle fiber.

2.0 Raw Material Availability & traditional application:

Coconut, the source of coir fiber, is largely produced along the coastal regions of India. The fruit is abundantly available (~10 million tonnes per annum), ranking first and sharing ~50% of global production. Yield varies from region to region (3500 to 6000 nuts/ha/year). One tree may yield on average 70-100 nuts to a maximum of 150 nuts per year. The kernel (copra, coco-water and shell) comprises 65 per cent of total weight, while the husk contributes 35 per cent.

Coir fibers are extracted from the husks as a by-product of copra production. The husks are left on the fields as a mulch or used as fertilizer because of high potash content. Only a small part of the fibers available worldwide are utilized for production of commercially useful products (Table 1). The average fiber yield is dependent on geographical area and the variety of the coconut tree. In the south of India and Sri Lanka, for example, where the best quality fibers are produced the average yield is 80-90 g fiber per husk.

Table 1 List of traditional coir products manufactured in India.

Car Mat	Coir Matting Tiles	Mesh Mats
Carnatic Mats	Coir Mattings	Multishaft Weave
Carpet Mats	Coir Needled Felt	Mural Coir Products
Carpets	Coir Pile Carpets	Non-woven Mats
Coir Braid Carpets	Coir Polymer Composites	Ribbed Mattings
Coir Cricket Matting	Coir Yarn	Rope Mats
Coir Geo Textiles	Corridor Mats	Rubberized Coir
Coir Gypsum Board	Creel Mat	Sinnet Mats
Coir Matting Mats	Fibre Mats	
Coir Matting Rugs	Loop Mats	

Husks are composed of 70 per cent pith and 30 per cent fiber on a dry weight basis. On average, the ratio of yield of long, medium and short fiber, respectively, is 60:30:10. Only a small part (less than 10 per cent) of the potential enters commercial trade. Continuous expanding production of brown fiber reached 216 000 tonnes (70 per cent India, 27 per cent Sri Lanka) in 1996, while white fiber production (again, mainly in India) has remained stable at 125 000 tonnes.

3.0 Swot analysis of Coir products:-

- Strength
  - Rigid natural fiber, capable to withstand higher compressive strength.
  - Highly durable product in respect of location suitability relating to heavy duty contract.
  - Long lasting without affected by moth, bacteria or other insects.
  - Less water absorbance.
- Weaknesses
  - Harsh fiber.
  - Less flexibility in handling coir product.
  - Moderate burning properties.
- Opportunities:-
  - A new prospective product line in handmade sector.
  - Occupying hygienic functional properties like acupressure, maintains normal indoor air quality with minimum generation of mites.
  - A value engineered product.
- Threat
  - To face strong competition with other fibers like wool, nylon, polypropylene and viscose etc.

4.0 Value Addition present status through collaborative project amongst IICT & CCRI:

Value addition of the fiber is done in terms of conversion to various products like brushes and brooms, ropes and yarns for nets and bags and mats, and padding for mattresses. Coir composites with synthetic resins has developed as a new area for product development.

In consideration of all these aspects an attempt was taken in this project to develop new avenues for promotion of coir products. The details of the activities of IICT and output are described in the following section.

- Value added doormat:.
- To conduct laboratory experiments on pulping & bleaching of coir fibers samples for optimization of various parameters to produce high alpha cellulose pulp.
- To develop pre-treatment process for complete removal of pith.
- Preliminary laboratory level study to explore regeneration of cellulose from coir.
- Development of vertical blind from coir based fabric.
- Carpet backing using coir based scrim fabric.
- Development of Q –Master using coir blended fabric and appropriate treatment.

5.0 Value Addition prospects:-

Coir fiber is abundantly available at reasonably low or no cost, especially those from tender coconut which are just thrown away as garbage after consuming coconut water can be used for scope for more value addition to coconut growers. Niche product in the name of Coir Silk or coco silk can be made available.

Scope of the study:

- Conversion of coir fiber to rayon grade pulp.
- Conversion of rayon grade pulp to fiber and / or filament.
- Application of development fiber and /or filament for product development.

6.0 Conclusions:-

The results obtained through above experimental study depict a preliminary data base achieved through development of samples for taking trials. Further development are required for achieving coir silk, coir derivatives at the end use of home textiles.

7.0 Acknowledgement :-

IICT, thankfully acknowledges contribution of coir board (Ministry of ARI. Govt. of India) CCRI, Alleppey, Kerala for sponsoring the project, “Collaborative project between IICT and Coir Board, Validation of intellectual property of IICT” by signing an MOU with IICT, Bhadohi.

Design and Development of Children's Products using Coconut Fibre

by

National Institute of Design, Ahmedabad and Central Coir Research Institute, Kalavoor

Abstract

The paper presents the approach and accomplishment of NID-CCRI collaborative project on Design and Development of Children's Products using Coir Fibre as the main raw material so as to create a product system that will provide value addition as well as sustainable livelihood opportunities for the marginalized coir workers and alternative sustainable eco-friendly material for products in this area.

The main approach was to exploit unique abilities of coir as a material like the burning qualities, toughness, eco friendliness, bounciness in design and development of products. The research study brought out contemporary concerns regarding the type of manufacturing scenario available in certain parts of the country. The abilities and possibilities of various agents in the coir processing and production were also accounted for while coming up with concepts. for e.g. the abilities of the experienced and aged coir workers was made use of in creating safe cracker lighting stick to be used by a child or create novel Christmas decoration items meant for export market. The possibility of a co-creation between adult and child is explored in concepts concerning products for the children's room. Game as a mode of immersive play was explored to create Cocopoly which encourages the child to become the biggest coir manufactures at the same time exposing them to various natural as well as social conflicts while doing so.

Children's Coir Products namely (1) Cocopoly Game (2) Fire Cracker Lighters (3) Christmas Decoration and (4) Coir Skin Lamp Shade developed under project have been covered in this paper. It was also shown to the coir manufacturers who viewed it with great interest and appreciated the developments. The know-how for technology transfer to the industry has also been made ready.

This has demonstrated how design-technology intervention can help in finding appropriate and sustainable design applications using coir fibre as primary material. However, this calls for a major and continuous design-technology intervention in the sector.

Potentials of Coir as technical textile fibre

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Introduction

Coir, in comparison with other natural fibres , is one of the hardest natural fibres because of its high content of lignin. Coir fibres have been hitherto considered mainly for door mats and floor furnishing. However, due to the pioneer research works of two research institutes of Coir Board, coir fibres have found use as technical textiles in different fields of applications. Technical textile is a textile product where function is the primary criterion. It is a large and growing sector and supports a vast array of other industries. Technical textiles include textiles for automotive applications, medical textiles (e.g., implants), geo-textiles (reinforcement of embankments), agro-textiles (textiles for crop protection), and protective clothing (e.g., heat and radiation protection for fire fighter clothing, molten metal protection for welders, stab protection and bulletproof vests, and spacesuits). Over all, global growth rates of technical textiles are about 4% per year greater than the growth of home and apparel textiles, which are growing at a rate of 1% per year.

The following unique properties of coir give it an edge over the other natural and synthetic fibres;-

- Of all natural fibres coir possesses the greatest tearing strength, even in very wet conditions.
- Unlike most synthetic fibres, coir fibres are non-thermoplastic—that is, they do not soften when heat is applied.
- Coir fibres show little sensitivity to dry heat, and there is no shrinkage or high extensibility upon heating.
- The fibre is hygroscopic, with moisture content of 10 to 12% at 65% relative humidity and 22 to 55 % at 95% relative humidity.
- Coir can withstand huge amount of weight and rubbing and recovers, as soon as the weight is removed from it.
- They are porous having a lot of air pockets to act as good insulators.
- Coir fibre is in demand for its toughness, strength, resistance to dampness, rot resistance, durability and natural resilience, porous, hygroscopic and biodegradable properties.
- They have excellent acoustic properties by virtue of their rough and rugged surface.
- They do not require anti UV treatment during field applications.

- They do not become brittle if cooled to below freezing
- Their thermal recycling is also possible.
- Coir is renewable, recyclable, and versatile.

In present market opportunities and in free quota system the importance of technical textile materials is increasing to accommodate the needs of requirement. Nowadays the most widely technical textile materials are used in filter clothing, furniture, hygiene medicals and construction material. Technical textiles can be divided into many categories, depending on their end use. The classification developed by Techtextil, Messe Frankfurt Exhibition GmbH is widely used in Europe, North America and Asia. The classifications are given in the following table:-

Agrotech Horticulture + landscape gardening, agriculture + forestry, animal keeping	**Meditech** Hygiene, medicine
Buildtech Membrane, lightweight + massive construction, engineering + industrial building.	**Mobiltech** Cars, ships, aircraft, trains, space travel
Clothtech Garments, shoes	**Oekotech** Environmental protection, recycling, waste disposal
Geotech Road infrastructure, Railways, Irrigation and Hydraulic structures, Waste Landfills, Dams etc.	**Packtech** Packaging, protective-cover systems, sacks, big bags, container systems
Hometech Furniture, upholstery + interior furnishing, rugs, floor coverings	**Protech** Person and property protection
Indutech Filtration, cleaning, mechanical engineering, chemical industry	**Sporttech** Sport and leisure, active wear, outdoor, sport articles.

Source: http://en.wikipedia.org/wiki/Technical_textile

COIR AS TECHNICAL TEXTILE

USE OF COIR AS AGROTECH

Textiles used in Agriculture are termed as agro textiles. They are used for crop protection, fertilisation. The essential properties required are strength, elongation, stiffness, and bio-degradation, resistance to sunlight and resistance to toxic environment. All these properties help the growth and harvesting of crops and other foodstuffs. There is a growing interest in using materials which gradually degrade.

Coir fibres when impregnated with natural rubber latex and moulded into suitable forms, can be used for manufacturing various types of garden articles like supporting poles for climbers, pots for nursery plants etc.

Coir non-woven fabrics have been used for making hanging flower growing pots which are very much popular in Europe.

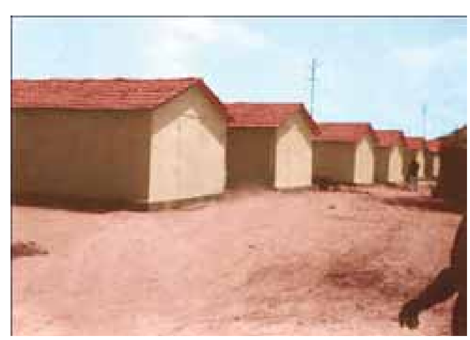
Coir nettings have been utilised for establishing net houses which provide ideal growing place for delicate plants by cutting sunlight up to 50%. Such net houses could also find use for establishing roof gardening. Such nettings when applied as underlay in green houses have been found to enhance the growth and yield due to creation of adequate humidity and favourable conditions for the plants.

Coir nettings when laid at a slope of around 60 degree, it can be used for growing vegetables like brinjal, ladies finger etc.

- ❒ Some of the potential examples of use of coir as agrotech are:
- ❒ Preventing erosion and paving way for afforestation in greenhouse cover.
- ❒ For layer separation in fields, nets for plants, rootless plants & protecting grassy areas.
- ❒ As sun screens (since they have adjustable screening) and wind shields.
- ❒ As packing material and in bags for storing grass/tea leaves (that has been mowed/plucked).
- ❒ Controlling stretch in knitted nets.
- ❒ Shade for basins.
- ❒ Anti-birds nets.
- ❒ Materials for ground and plant water management at the time of scarcity and abundance of water.

USE OF COIR AS BUILDTECH

Buildtech Textiles are used in construction - concrete reinforcement, façade foundation systems, interior construction, insulations, proofing materials, air conditioning, noise prevention, visual protection, protection against the sun, building safety.



Coir fibres when impregnated with phenol formaldehyde resin and converted into boards provide a wood substitute which finds use in the fabrication of low cost disaster management houses.

This product name as coir wood finds use for manufacturing various articles like false ceiling boards, window and wall panels, furniture, corrugated roof sheets etc.

Recent studies conducted by the CCRI of Coir Board have established that the coir pith when pressed at certain temperature and pressure it can be converted into solid insulation boards which can be effectively used for keeping the buildings insulated from heat, cold and noise when laid on the inner walls.

USE OF COIR AS CLOTHTECH

Technical textiles for clothing applications are especially in the finishing process where fabric is treated under pressure and high temperature the technical textile supports the fabric for smooth processing.

Coir Board has recently developed mobile coir fibre extraction machine which extracts coir fibres and pith for the coconut husk in 10 seconds. The fibres obtained by this process are subjected to dew like spray treatment with a biochemical solution which bestows the coir fibres a soft and supple feel. Such fibres produce a soft and finer yarn of runnage up to 1000 meters/kg which are being utilised for manufacturing cloths in union with cotton/silk yarn to produce the garments like warm jackets for extremely cold climates at high altitudes. When these fabrics are treated under heat and pressure they are obtain smooth finish.

USE OF COIR AS GEOTECH

Topsoil is essential to food production. Without it retention of water is greatly diminished. Additionally, the sub layers beneath the topsoil are more compact and therefore water is more apt to run off than be absorbed. To make these exposed sub layers even marginally productive, large amounts of fertilizer need to be applied. Unfortunately, the available land for growing food is a finite nonrenewable resource. That's right, we lose topsoil faster than it is naturally produced (it takes about 200 - 1000 years to produce an inch of topsoil). Worldwide, the annual loss is about 26 billion tons. More and more, farmers have to be made aware about the beneficial use of coir geotextiles for protection from water and wind.

Coir geotextiles are used in reinforcement of embankments or in constructional work. The fabrics in geo textiles are permeable fabrics and are used with soils having ability to separate, filter, protect or drain. The application areas include civil engineering, earth and road construction, dam engineering, soil sealing and in drainage systems. The fabric used in it must have good strength, durability, low moisture absorption and thickness. Mostly nonwoven and woven fabrics are used in it. These are used to prevent cracking of the concrete, plastic and other building materials. Other areas of applications are dry/liquid filtration depending on their compatibility.

Coir geotextiles are available in the form of woven and non-wovens and cocologs. The Coir Board has formulated and got BIS specifications for coir geotextiles based on the field studies carried out in different parts of the country.

Coir geotextiles have been used for soil erosion control and paved and un-paved road construction. National Rural Road Development Agency (NRRDA), Govt. of India has approved the construction of 450km of rural roads in 9 states of the country under Pradhan Mantri Gramin Sadak Yojana (PMGSY) using coir geotextiles which have also got the accreditation of Indian road Congress (IRC). Coir Board has already initiated the work in collaboration with four state level technical agencies namely, College of Engineering and Technology, Thiruvanathapuram, National Institute of Technology (NIT), Calicut, NIT, Thiruchirapally and Maulana Azad National Institute of Technology (MANIT), Bhopal. The control of reflective cracking of road surfaces has also been demonstrated by the use of coir geotextiles along with bitumen.

Coir Board has been consistently attending and presenting papers on applications of coir geotextiles for various geotechnical purposes in the Annual Conference of International Erosion Control Association (IECA), held at USA.

USE OF COIR AS HOMETECH

Textiles used in a domestic environment - interior decoration and furniture, carpeting, protection against the sun, cushion materials, fireproofing, floor and wall coverings, textile reinforced structures/fittings fall in this category.

Coir mats and matting have been traditionally used for home furnishing. PVC and rubber tufted mats have found an edge in the export market. Considering that the Coir Board has developed a mini tufting machine under Public Private Partnership (PPP) so as to produce such mats on low cost indigenised machine to meet the increasing domestic market demand.

With the development of fine yarn out of coir sisal blending it has been possible to produce coir curtains, venetian blinds, light weight mats. These products are also available in the dyed form using natural eco-friendly dyestuffs.

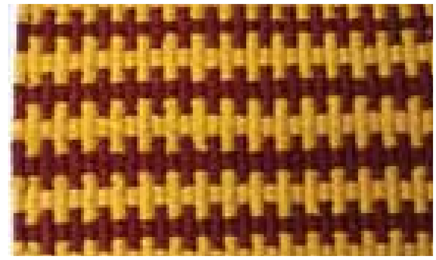
USE OF COIR AS INDUTECH

Sound-proofing in industrial environment provides adequate scope of using coir fabrics, Coir wood, coir pith binderless boards which requires further studies. As a pilot project Coir Board has undertaken a job work to provide insulation in badminton-cum-theatre hall of the Railway Wheel Factory, Bengaluru.

Coir fabrics are generally fire retardant; however, to enhance the properties for meeting international specifications, a formulation has been developed by the Board to make coir fabrics fire retardant. Railways have shown keen interest in the fire retardant coir for furnishing of railway coaches.

USE OF COIR AS MEDITECH

Coir yarn has been made finer, thanks to its blending with other natural fibres like sisal. The fine cloth is infused with the herbs of traditional Indian medicine as it has got the potential for curing many stress related conditions such as insomnia. This cloth has been named by the Hon'ble Chairman, Coir Board as Ayurcoir. The colours on the ayurcoir are produced from the medicinal preparation only and no other colourants are used. The roots, flowers, fruits, leaves, barks of different herbs are used to make dyes.



Coir fabrics have been used for creating healthy atmosphere for the patients suffering from diseases like arthritis, asthma etc. The coir fabrics are dyed using eco-friendly natural colours and ayurvedic medicines which provide natural cure to the patients. The product known as Ayurcoir is gaining popularity because of its eco-friendliness.

Nanaocellulose has been recently extracted from coir pith which has potential uses in the wound dressings etc.

USE OF COIR AS MOBILTECH

These textiles are used in the construction of automobiles, railways, ships, aircraft and spacecraft.

Coir fibres when extruded with polypropylene could produce high tenacity products with low specific weight. Such products have potential use in the areas of making dash boards for automobiles and various parts in railways and ships etc. Rubberised coir sheets provide high durability and cushioning properties by virtue of which they will find use in car seats.

Non-woven coir felt has potential of use in the car trunk coverings with minimum airborne fibres unlike synthetics.

USE OF COIR AS OEKOTECH (ECOTECH)

Newer applications for textiles in environmental protection applications include floor sealing, erosion protection, air cleaning, prevention of water pollution, water cleaning, waste treatment/ recycling, depositing area construction, product extraction, domestic water sewerage plants.

Cocolawn a readymade lawn developed by the Coir Board using coir netting, coir non-woven, coir pith and coir pith organic manure has various eco friendly applications which include creating instantaneous greenery on rocky patches or any arid surface. The ready-to-use COCOLAWN is made available in the form of a blanket, which can be shifted from one place to another and can be rolled upon for transportation. The harmful effects of chemical fertilisers to the environment are well known. In this invention Coir Pith Organic Manure (C-POM) has been utilised as a source of soil less, pesticide free, nutritional medium for healthy growth of natural grass in an environment friendly manner. Replacement of soil makes the Cocolawn much lighter in weight also which helps in transportation and installation. Normally the synthetic lawns are treated with ultraviolet radiation resistant chemicals to extend durability. The disposal of such synthetic lawns becomes a problem. The coir materials do not require such treatments as the presence of large amount of surface lignin nullifies the effect of UV light. Unlike synthetics the COCOLAWN does not pose any ingestion risk to wild life. Typical applications include ground cover, roof cover, and cycle path and footpaths and vegetation restoration in any denuded areas.

USE OF COIR AS PACKTECH

Coir wood has been used for making lids of packaging boxes for transportation of chemicals. Collapsible packaging boxes have also been developed in collaboration with Indian Institute of Packaging (IIP), Mumbai.

USE OF COIR AS PROTECH

The Coir Board has developed an umbrella which is an effective Ultra Violet (UV) rays' cutter from sunlight providing protection to the human skin against UV rays. Such umbrellas could also find use for protection against sun rays on sea beaches, juice parlours etc.

Protective clothing viz. a ballistic woven material for Body Armour could be developed using natural & synthetic fibres like kenaf and aramid in the ratio of 50:50. Studies on coir as potential material for the Anti Stab and Blunt Trauma for the anti ballistic applications have been conducted.(Maziah Mohamad et al. Armour Factory,Malaysia

USE OF COIR AS SPORTTECH

Coir matting have been used as gymnasia matting and cricket pitch matting.

CONCLUSION

Of all natural fibres coir possesses the greatest tearing strength, even in very wet conditions. Coir fibre is in demand for its toughness, strength, and resistance to dampness, rot resistance, durability and natural resilience, porous, hygroscopic and biodegradable properties. It is renewable, recyclable, and versatile. Coir is wrinkle-resistant, strong, and impervious to abrasive wear. It can stand exposure to weather, especially water, so it proves to be a technical textile fibre for diversified end use.

ACKNOWLEDGEMENT

Grateful acknowledgements are due to Shri. C. P. Radhakrishnan, Hon'ble Chairman, Coir Board for his keen interest, encouragement, support and continued guidance in all the R&D activities of Coir Board.

USE OF COIRGEOTEXTILES IN UNPAVED ROADS

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ABSTRACT : Geotextile made of coir are ideally suited for low cost applications because coir is available in our country in abundance at very low price compared to other synthetic geotexiles. These geotextile can be applied in the construction of unpaved roads where they can be effectively serving the purposes of reinforcement, separation, filtration and drainage. This study examines the improvement in the performance of unpaved roads constructed on silty soils using coir geotextile reinforcement through a number of model tests. The strength aspects of non woven and woven coir geotextile have been studied by performing CBR tests and Plate Load Tests.

INTRODUCTION

A large variety of detrimental factors affect the service life of roads and pavements including environmental factors, subgrade conditions, traffic loading, utility cuts, road widening, and aging. These factors contribute to an equally wide variety of pavement conditions and problems, which must be addressed in the maintenance or rehabilitation of the pavements, if not dealt with during initial construction.

Problems of pavement distress are often classified into those attributed to structural deficiencies and those resulting in loss of function of the roadway. Structural deficiencies arise by the loss of mechanical properties that govern the load carrying capacity of the roadway or by an increase of load for which the roadway was not designed. In either case, structural deficiencies result in the loss of roadway's ability to carry vehicular load. The loss of functional capacity of the roadway typically involves the development of an excessively rough riding surface that results in discomfort to the road user. Functional problems such as pavement surface cracks, rutting, potholes and asphalt bleeding etc., if left uncorrected, can lead to the development of a structural problem.

Pavement maintenance treatments are often ineffective and short lived due to their inability to both treat the cause of the problems and renew the existing pavement condition. The main cause of distress in pavements is that they are quite permeable with 30 to 50% of precipitation surface water infiltrating through the pavement, softening and weakening the pavement subgrade and base, accelerating pavement degradation. Existing pavement distress such as surface cracks, rocking joints, and subgrade failures cause the rapid reflection of cracking up through the maintenance treatment. Therefore, the preferred strategy for long-term road and pavement performance is to build in safeguards during initial construction. These performance safeguards include stabilizing the subgrade against moisture intrusion and associated weakening; strengthening road base aggregate without preventing efficient drainage of infiltrated water; and, as a last resort, enhancing the stress absorption and moisture proofing capabilities of selected maintenance treatments. Geosynthetics are proved to be the most cost effective tools for safeguarding roads and pavements in these ways. The functions of geosynthetics in roads fall into the following categories: subgrade separation and stabilization, base reinforcement, filtration and drainage, overlay stress absorption and overlay reinforcement.

Here an attempt is made to utilize coir geotextiles for subgrade improvement by exploring its functions for subgrade stabilization and separation.

SUBGRADE SEPARATION AND STABILIZATION

Temporary roads used for hauling and access roads that are subject to low volumes of traffic are often constructed without asphalt or cement concrete surfacing. In these cases, a layer of aggregate is placed on the prepared subgrade of these roads to improve their load carrying capacity. As an aggregate layer is loaded, the bottom loosens with tension cracks allowing the underlying fines, under pressure, to migrate up into the aggregate. As little as 10 percent to 20 percent fines can completely destroy the structural strength of the aggregate by interfering with the hard, stone to stone contact. As fines infiltrate a portion of the structural section, flexure increases, fines migrate further upwards and the section deteriorates until complete structural section failure occurs. This process can quickly destroy the effectiveness of several inches (millimeters) of aggregate. Contamination of the base course layer leads to the reduction of strength, stiffness and drainage characteristics. Problems are usually encountered when the subgrade consists of soft clays, silts and organic soils. This type of subgrade is often unable to adequately support traffic loads and must be improved.

Typical Solutions

Excavating and replacing unsuitable materials is costly and time consuming. Other methods of subgrade improvement include deep compaction, chemical stabilization and preloading.

Geotextile Solution

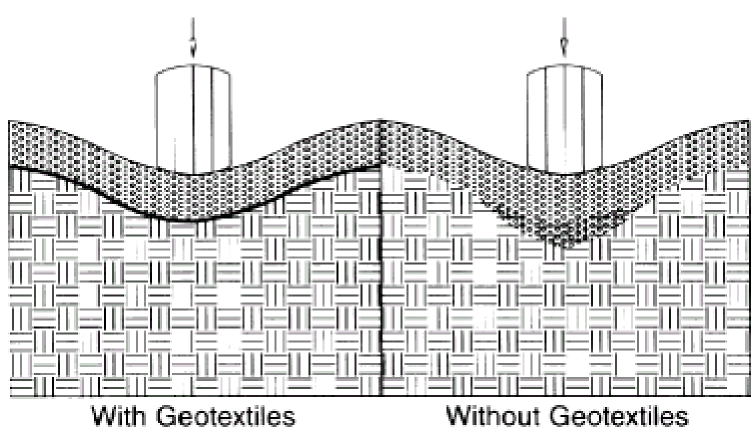

Fig.1 Geotextile as Separator

Geotextiles are proving to be a cost effective alternative to traditional road construction methods. Geotextiles provide a separation layer between the aggregate and the subgrade soil, to prevent migration of fines and thus indefinitely preserve the original aggregate structural thickness.

The function of separation refers to the ability of the Geotextile to provide physical separation of subgrade and base materials both during construction and during the operating life of the roadway.

The function is defined by prevention of mixing, where some type of mechanical action causes mixing. Mechanical action causing mixing generally arises from physical forces imposed by construction or operating traffic and may cause the aggregate to be pushed down into the soft subgrade and/or the subgrade to be squeezed up into the base aggregate. A properly designed separator allows the base course aggregate to remain *clean* which preserve its strength and drainage characteristics.

Here the strength and modulus of Geotextile is important only to ensure survivability of the material during construction and operation of the roadway. In this the geotextile separator itself is not viewed to contribute structural support to the roadway whereas it ensures that the base course layer in its entirety will contribute and continue to contribute its intended structural support of vehicular loads. This view point advocate the use of comparatively low strength coir geotextiles in subgrades.

Geotextile Benefits

The geotextile usually costs no more than 2 inches to 3 inches (50 mm to 75 mm) of compacted, in-place aggregate, but can save several inches (millimeters) of aggregate. The separate function is more dramatic over weak subgrade soils, but is economically practical in the long run to use even on more competent subgrades.

Geotextiles are recommended for this separation function because of their low cost, coefficient of friction, elongation and drape to conform to any surface, effective filtering even after elongation, abrasion and puncture resistance, and their high coefficient of permeability.

One extra benefit of using a geotextile for separation is that almost all the aggregate over the geotextile can be reclaimed and reused. This is particularly economical in temporary uses such as mine haul or logging roads or anywhere aggregate is expensive and equipment is available to reclaim the uncontaminated stone.

BASE REINFORCEMENT

Permanent roads carry larger traffic volumes and typically have asphalt or Portland cement concrete surfacing over a base layer of aggregate. The combined surface and base layers act together to support and distribute traffic loading to the subgrade. Problems are usually encountered when the subgrade consists of soft clays, silts and organic soils. This type of subgrade is often water sensitive and, when wet, unable to adequately support traffic loads. If unimproved, the subgrade will mix with the road base aggregate – degrading the road structure - whenever the subgrade gets wet. Poor roads often result from poor subgrades

Typical Solutions

As with unpaved roads, a problematic subgrade is typically excavated and replaced, or it is improved by the addition of cement, lime, or excess aggregate. In any case, the traditional solution is often costly and always time consuming.

Geotextile Solution

The reinforcement mechanisms, provided by all types of nonwoven and woven geotextiles, are widely recognized. Geotextiles are used in reinforcement through mechanisms of restraint or confinement,

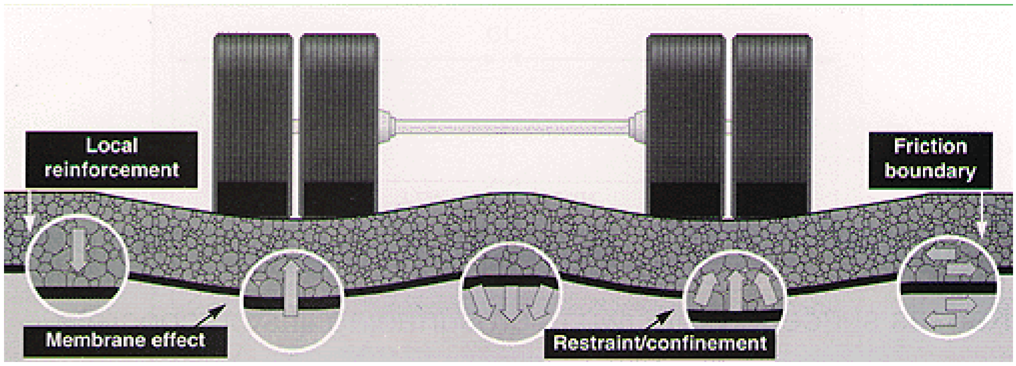

Fig. 2 Reinforcement Action

friction, membrane effect and local reinforcement.

In roads, lateral restraint also called confinement is considered to be the primary function of the geotextiles. With the addition of an appropriate geotextile, the Soil-Geotextile-Aggregate (SGA) system gains stiffness. The stiffened SGA system is better able to provide the following structural benefits:

- Preventing lateral spreading of the base
- Increasing confinement and thus stiffness of the base
- Improving vertical stress distribution on the subgrade
- Reducing shear stress in the subgrade.

Geotextile Benefits

A Geosynthetic Materials Association (GMA) review of geosynthetic base reinforcement identified the most common method for quantifying geosynthetic benefits as the determination of a Traffic Benefit Ratio (TBR). The TBR relates the ratio of reinforced load cycles to failure (excessive rutting) to the number of cycles that cause failure of an unreinforced road section. In general, geosynthetics have been found to provide a TBR in the range of 1.5 to 70, depending on the type of geosynthetic, its location in the road, and the testing scenario.

In India the design of roads mainly based on the CBR values of subgrades. The research on coir geotextiles showed that the introduction of coir geotextile in subgrade soil drastically improve the CBR value in all types of soil, both in dry and soaked conditions.

DRAINAGE / FILTRATION

The drainage/ filtration function of a geotextile can be critical to structural section performance.

Filtration refers to the ability of geosysnthetics to filter fine soil particles from the subgrade from intruding into the base when water flows from subgrade into the base. Water flow is most likely produced by the generation of excess pore water pressures in the subgrade as a result of repetitive traffic. Fines contained in the subgrade may become suspended in the pore water as a result of shearing action and can be carried into the base in the absence of a proper filter.

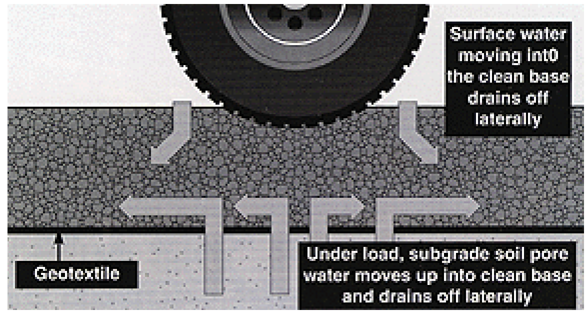

Fig. 3 Drainage Application

The key to this application lies in the ability of geosynthetic to filter fines without becoming clogged. Since a layer of suitable geotextile keep the base course clean and permit the free drainage with out clogging, the pore pressure will not develop within the base course and keep its strength constant. With the need for a geotextile filter established, a geotextile having characteristics necessary to prevent fines migration can be selected.

COIR AS A SUITABLE GEOTEXTILE MATERIAL FOR ROADS

The following discussions reveal the suitability of coir as a geotextile material:

As Reinforcement

Reinforcement is one of the most important functions of geotextiles in improving the soil properties, whether it is used in slope, embankments, and retaining wall or in pavements. When reinforcement is placed in soil it can develop bond through frictional contact between the soil particles and the reinforcement surface. Deformation in the soil mobilizes tensile or compressive force in the reinforcement depending on the inclination of the later and is ultimately limited by the available bond between soil and reinforcement. Hence the shear frictional behaviour of soil-geotextile interfaces

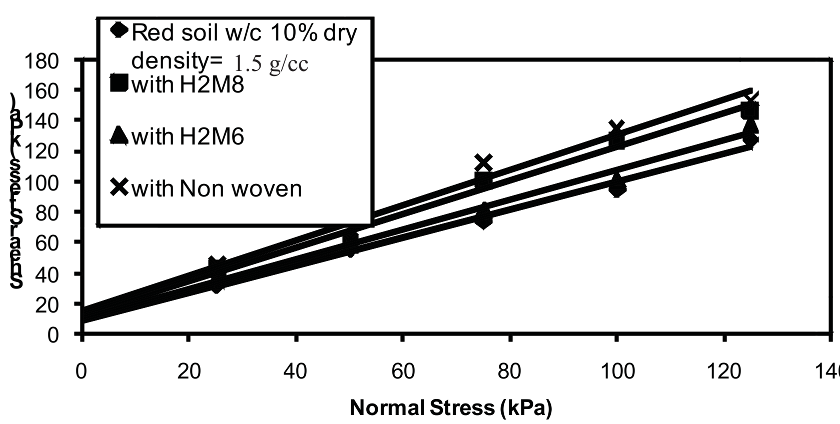

Fig. 4 Variation of Peak Shear stress vs. Normal Stress for red soil -Coir Geotextile Interface

places a pivotal role while analyzing the overall performance of geotextile reinforced constructions. The interfacial friction depends upon a large number of parameters such as pressure, grain size and shape , surface roughness of geotextile etc.. Modified Direct shear tests are suitable for measuring the coefficient of friction between soil and reinforcement.

It could be seen that interfacial friction is more with NW coir geotextiles. The NW coir geotextiles are in full contact with the soil, more soil grains are mobilized in the shearing process. Comparing H2M6 and H2M8 woven coir geotextiles, it could be seen that H2M8 coir geotextile performs better than H2M6 coir geotextile in all soils tested. This may be due to the lesser contact area of woven coir geotextiles depending on their mesh size.

One of the important functions of geotextiles is to increase the bearing capacity of the soil. The reinforcement consists of placing reinforcing elements such as strips, bars, sheets, grids, cells etc. in the soil. This can be placed in single layer or in multiple layers.

In order to understand the beneficial effect of different type of coir geotextiles as reinforcement, load settlement graphs were plotted for a specified value of z/B. Fig. 2 shows the load settlement behaviour for z/B = 0.5

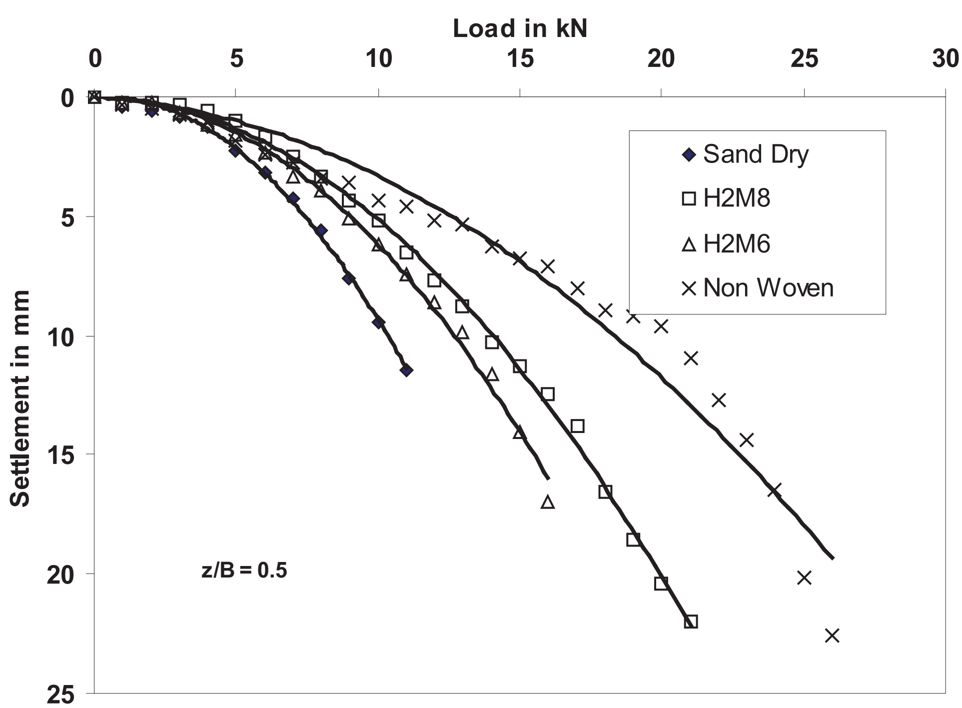

Fig.5 Load Settlement behaviour with Coir geotextiles placed at z/B=0.5

As separator

The separator aspects of coir geotextile have been studied by performing plate load model tests within a test tank .The tests were conducted by applying static loads on base course through a plate of 200mm diameter. The test was repeated by placing geotextile at the interface between soil and base course. The test was conducted with woven and nonwoven coir geotextile.

Here also placement of a single layer of geotextile improves the supporting power of the subgrade more than two times. Here in addition to the function of reinforcement, the geotextile perform as a separator also and thereby prevents the mixing of subgrade and the coarse material for the base. These factors increase the carrying capacity also.

As filter/drainage layer

One of the major functions that getotextiles perform is that of filtration. Here water flows through geotextile. Permeability Tests can be done to evaluate the amount of water per unit area passing through a geotextile. Here, in the case of coir geotextiles, this property is relevant only in Non-woven the others being mesh with very high permeability. Cross plane permeability of the Nonwoven geotextile tested were found to be approximately 0.025cm/s, which is much higher than that of the usual types of soil.

Strength of subgrade

The strength of the subgrade is most often expressed in terms of California Bearing Ratio (CBR). The values of Modulus of subgrade reaction and resilient modulus of soil have been correlated with CBR value. In India the design of flexible pavement make use of primarily the subgrade CBR (IRC: 37 – 2001). It gives in terms of load against standard penetration. A typical test result of the CBR tests conducted is shown which depict the influence of type coir geotextle in CBR. In all cases the CBR values are found to be much higher than the ordinary soil alone.

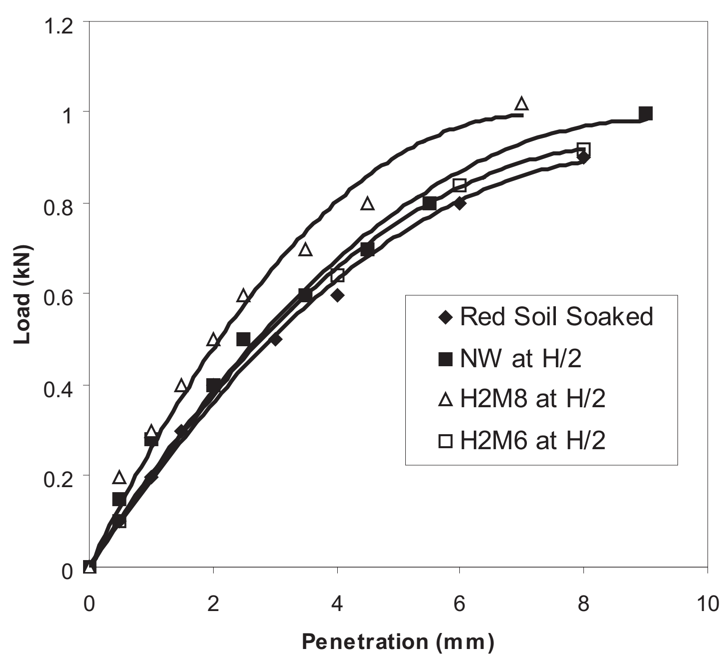

Fig 6. Effect of Type of Reinforcement on load penetration

The result of the study indicates that the CBR value of the soil reinforced with coir has improved and also non woven coir showing better result than woven coir geotextile. From the plate load test also it is found that the settlement can be reduced with non woven coir geotextile and woven coir geotextile and the better perfomance is with nonwoven coir.

FIELD INSTALLATION OF GEOTEXTILE

Regardless of subgrade strength, the site should first be cleared of all sharp objects, tree stumps, and large stones that could puncture the fabric. Unless it is necessary to achieve final grade, the vegetative mat need not be removed, because it can provide extra support during aggregate placement until final compaction. Brush or cushion layers under the nonwoven fabric are usually necessary, since the fabric prevents soil fines from pumping into the aggregate layer.

Geotextiles should be rolled out onto the subgrade by two people, beginning at a point that allows easy access for construction equipment, yet is consistent with the layout plan. On very soft subgrades, the fabric layout and aggregate placement should begin on the firmest soil on the site perimeter, as an anchor point. From there the fabric can be rolled onto softer sections.

Fabric overlaps and seams should be made as specified. In windy weather, soil or rocks should be placed on the fabric to hold it down until aggregate is placed. Ground securing pins are sometimes used in the overlap sections of the geotextiles.

A compactable, non-moisture sensitive aggregate is then back dumped onto the geotextile beginning on firm soil at a point just in front of the geotextile. This should anchor the geotextile firmly. The aggregate is then spread in one lift to a thickness greater than that needed for stabilization to allow for subsequent compaction. If the thickness from one lift is too great for satisfactory compaction, place more than one lift. In any situation, the first lift should be as thick as necessary to prevent the compaction from overstressing the subgrade. The bulldozer must blade into the load and slightly upward during aggregate spreading for the same reason.

This procedure is followed for each load until the fabric is completely covered.

Over very soft subgrade, care must be taken during aggregate placement to insure the fabric is not moved out of position nor the subgrade overstressed. The bulldozer operator can best determine which spots need additional aggregate for good stability by watching for rutting in the aggregate layer.

Vehicles should not be allowed to drive directly on the geotextile. If the geotextile is damaged during installation, the damaged section should be exposed and a patch of geotextile placed over it. The patch should be large enough to overlap onto unaffected areas by 3 to 4 feet (1 to 1.25 meters). The aggregate is then replaced and compacted by the bulldozer. Geotextile panels should be overlapped both side-to-side and end-to-end from 1.5 feet to 3 feet (0.5 to 1 meter), depending on subgrade strength.

Final compaction is achieved with a vibratory compactor, first without vibration for several passes, then with full vibration. Any weak spots found during final compaction usually indicate inadequate aggregate thickness at those spots. Do not grade ruts down. Instead, fill them with additional aggregate and compact. This rule applies to any future rut maintenance required.

It is important that the construction process be monitored. If field conditions change from the design values, and cause a lower subgrade soil strength value, structural section thickness must be

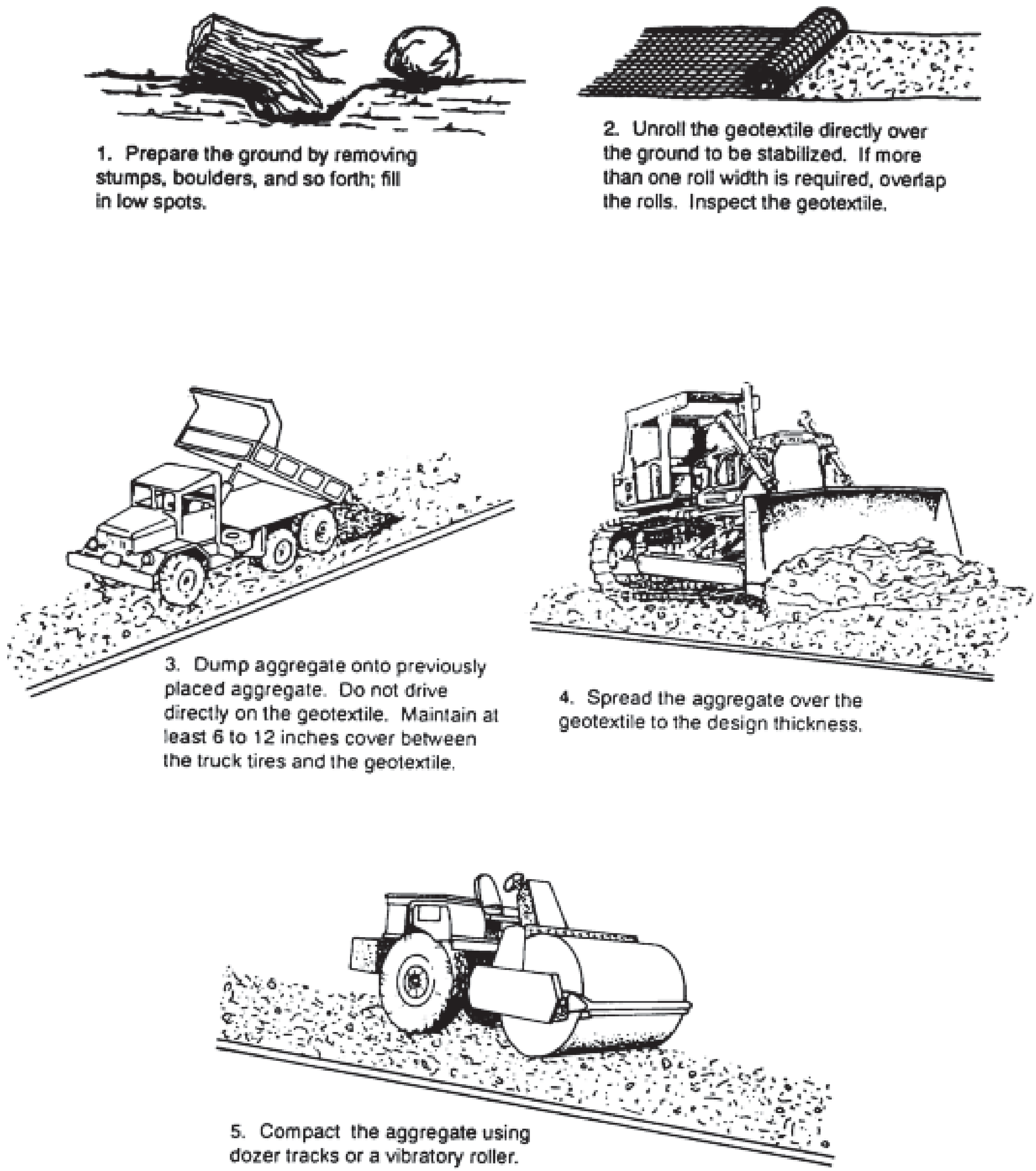

Fig. 4 Construction Sequence

re-evaluated. Monitoring construction and early use of the aggregate section pinpoints weak areas missed in soil testing.

Equally important is monitoring the quality of the structural section materials and the placement method. The purpose is to detect changes so, if necessary, design adjustments can be made on site before excessive subgrade failures occur. Careful planning and preparation for each installation step speed up the construction and insures good performance and full benefit from geotextiles.

CONCLUSION

The following points in connection with use of coir geotextile to aid in support of traffic loads is established.

- *Base (or Subbase) Reinforcement* - the use of a coir geotextile as a tensile element at the bottom of a base (or subbase) or within a base course to:

  1) improve the service life, and/or

  2) obtain equivalent performance with a reduced structural section.

Base reinforcement is applicable for the support of vehicular traffic over the life of the pavement and is designed to address the pavement distress mode of permanent surface deformation or rutting

- *Subgrade Restraint* - the use of a geosynthetic at the subgrade/subbase or subgrade/base interface to increase the support of construction equipment over a weak or low strength subgrade.

The primary result of this application is increased bearing capacity. Lateral

restraint and/or tension membrane effects may also contribute to load-carrying capacity. Subgrade restraint is the reinforcing component of stabilization.

- The following benefits of using coir geotextile in unpaved roadways are identified:

  1. Reducing the intensity of stress on the subgrade (function: separation).

  2. Preventing subgrade fines from pumping into the base (function: filtration).

  3. Preventing contamination of the base materials allowing more open-graded, freedraining aggregates to be considered in the design (function: filtration).

  4. Reducing the depth of excavation required for the removal of unsuitable subgrade materials (function: separation and reinforcement).

  5. Reducing the thickness of aggregate required to stabilize the subgrade (function: separation and reinforcement).

  6. Minimizing disturbance of the subgrade during construction (function: separation and reinforcement).

  7. Assisting the increase in subgrade strength over time (function: filtration).

  8. Minimizing the differential settlement of the roadway, which helps maintain pavement integrity and uniformity (function: reinforcement).

  9. Minimizing maintenance and extending the life of the pavement (functions: all).

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STUDY ON THE LONG TERM PERFORMANCE OF COIR GEOTEXTILE REINFORCED FLEXIBLE PAVEMENTS USING DCP TEST

1. INTRODUCTION

A wide network of road transport plays a major role in connecting different places in India and it is the only reliable transport medium of many rural people. While constructing a pavement, it is designed for a period of 20years. But in actual situation, the service period is always less than the design period. One of the major reasons for the failure of pavement is its weak subgrade. Maintenance treatments of such failures are often ineffective or short lived due to their inability to treat both the cause of the problems and renew the existing pavement condition. Therefore the preferred strategy for long-term pavement performance is to build in safeguards during initial construction.

There are different techniques to stabilize soil subgrade like excavating the soft soil and refilling, chemical stabilization using lime, cement etc, or by using geosynthetics. The application of geosynthetics in pavement construction and maintenance is an effective option in a country like India where the raw materials and labour can be easily made available. The use of geosynthetics in pavements is not novel, it started in late 1970s.

According to ASTM 2000, Geosynthetic is a planar product manufactured from a variety of synthetic polymer materials that are specifically fabricated to be used in geotechnical, geoenvironmental, hydraulic and transportation engineering related materials as an integral part of a man-made project, structure or system. Polyethylene, polyester, polypropylene, nylon etc. are the common polymers used in the manufacturing of geosynthetics. Geotextiles, geogrids and geocomposites are the commonly used geosynthetics in pavements. They perform mainly three major functions: separation, reinforcement and drainage. They also prevent the mixing of subgrade with the base course, provide stiffness and strength to pavement and allow proper drainage of the pavement and thus increasing the life of paved roads.

Natural geotextiles made from coir fibres, jute, sisal etc can be used as an alternative to polymeric geosynthetic materials. The main advantage of natural material is that it enables the use of local materials and the design becomes cost effective and sustainable. Also skilled labour and heavy machineries are not needed. But since the fibres are biodegradable, the strength of the pavement varies with time. In order to study its effect, a long term performance study of coir reinforced pavement has to be done.

In this paper, six flexible pavements reinforced with coir geotextiles in 2011 are taken for study. The performance of pavement is evaluated using Dynamic cone penetrometer and visual evaluation are reported.

2. LITERATURE REVIEW

The geotextile acts as a tensioned membrane and reduce the vertical stress acting on the subgrade (Giroud and Noiray, 1981). The placement position of the reinforcement is the major factor affecting the bearing capacity of reinforced granular soil and higher bearing capacity has been observed when the depth of placement of reinforcement is decreased (Sankariah and Narahari, 1988). The presence of reinforcement layer increases lateral restraint or passive resistance of the fill material, increasing the rigidity of the system and reducing the vertical and lateral pavement deformation (Ajitha and Jayadeep, 1997; Cancelli and Montanelli,1999; Perkins,1999; Som and Sahu ,1999) Reinforcement placed high up in the granular layer hinders lateral movement of the aggregate due to frictional interaction and interlocking between the fill material and the reinforcement which raises the apparent load spreading ability of the aggregate and reduces the necessary fill thickness. (Perkins, 1999)

Natural geotextile like jute and coir are gaining importance because of their ecofriendly nature. There are several studies conducted on the application of different materials for improving the bearing capacity of weak soil. Coir is one of the reliable material to be used as a geotextile as it is strong and degrades slowly compared to other natural fibers due to high lignin content.

Models reinforced with geotextiles improves the bearing capacity of kaolinite (Rao and Dutta, 2006). The benefits of using reinforcements in flexible pavements depend largely on the quality and thickness of the granular base and location of the geosynthetics within the pavement structure along with other factors such as mechanical properties of reinforcement material, subgrade strength, nature of interaction between soil and geosynthetics and applied load magnitude (Al-Qadi et al, 2007) it is reported that maximum bearing capacity is obtained when woven and non-woven coir geotextile were used at the interface of silty clay subgrade and granular base course of 150mm thickness. It has been found that membrane effect of reinforcement diminishes with increase in the thickness of the road aggregate layer (Babu et al, 2008)

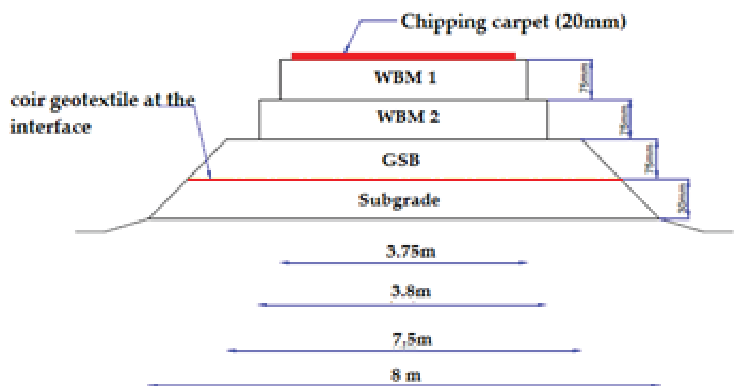
Saikia et al., 2010evaluated the effect of coir geotextile in improving the strength of the pavement and reducing its thickness and reported that he thickness of pavement found to be reduced by 75% after the intrusion of coir mat.

Senthil and Pandiammal (2011) studied the effect of needle punched nonwoven coir and jute geotextiles on CBR strength of soft subgrade and reported that coir geotextiles increases the CBR strength for 2.5mm penetration. The rate of reinforced to unreinforced is 1.5 for coir geotextile and 2.7 for jute geotextiles. Nithin et al., 2012 conducted studies on improving the bearing capacity of lateritic subgrade using coir geotextiles and reported that the load-carrying capacity of lateritic subgrade is improved and percentage reduction in settlement varies between 7% and 57%.

In all these papers researches are confined for a limited period of time and long term evaluation is necessary.

3. METHODOLOGY

Five pavements with CBR value less than three are selected for geotextile reinforcement after conducting preliminary soil property studies and the work commenced in 2011. The initial Roadway subgrade preparation typically involves removal of all vegetation, roots, and top soil. Localized soft or otherwise unsuitable subgrade areas are excavated and backfilled with select material. After preparing a subgrade layer of 30cm thickness, the coir geotextile is rolled out and sufficiently anchored to the soil. It is laid in the direction of construction traffic. Geotextile are overlapped both side-to-side and end-to-end, in the direction of aggregate placement. The recommended overlaps range from 1.5 to 3 feet, depending on subgrade strength. Coir geotextiles with 812 GSM (H2M5) are used in these pavements. After placing the geotextile, granular subbase layer of 75mm thickness and two water bound macadam layer of each 75mm are constructed, over which the bitumen layer is laid. The cross section of the pavement is given in figure 1. Photograph of pavement during and after construction are shown in Figure 2 and 3. Details of pavement are presented in Table 1 and 2.



Section of Pavement

Table 1-Name and length and date of constructionof test road

Designation	Name of Road	Length of road reinforced with Coir Geotextile	Date of construction
Road No 1	Attukal- Pampadi (Trivandrum Dist.)	150m	23/09/11
Road No 2	Karikuzhi- Chikidampara (Trivandrum Dist.)	470m	24/09/2011
Road No 3	Kumbarivila-Kollantemukku (Kollam Dist.)	1.168km	16/10/2011
Road No 4	ANC Jn.-Mulamootilpadi (Patthanamtitta Dist.)	2.500km	12/03/2012
Road No 5	Manakodam Ration kadaRoad (Alleppy Dist.)	750m	01/01/13
Road No 6	Puthusserikadavu-Kakkatikara (Ernakulam Dist.)	222m	08/12/11
Total		**5260m**	

Table 2. Subgrade Soil Properties

Sl No	Soil properties	Road 1	Road 2	Road 3	Road 4	Road 5	Road 6
1	Liquid limit (%)	42	35	46	41.4	65	61
2	Plastic limit (%)	25	19	26	11.73	39	29
3	Dry density (g/cc)	1.72	1.94	1.65	1.63	1.53	1.63
4	Silt and clay (%)	42.09	26.58	27.06	58.16	53.20	48.08
5	Soaked CBR	1.35	2.84	1.41	1.01	1.52	1.28

Fig:2 Construction of Coir geotextile Reinforced Pavement

Fig:3 Photogaph of the finished Coir Geotextile Reinforced Pavement

The pavement immediately after construction was opened to traffic. and to evaluate the performance of pavement, dynamic cone penetrometer test (DCP) was conducted. A schematic diagram of the DCP is shown in Figure 4.

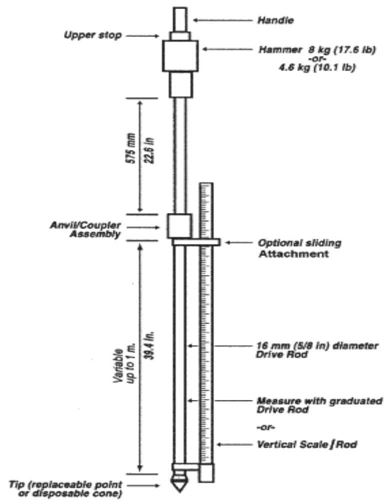


Fig:4 Schematic diagram of DCP

Testing were conducted as per the procedure given in ASTM D6951/D6951M- 09. Using a core cutter or suitable instrument, a hole is made such that its lowest point is a few centimeters above the subgrade layer. Once the layer to be tested has been reached, a reference reading is taken and the thickness of the layers cored through is recorded. This reference reading is the point from which the subsequent penetration is measured.

The DCP device is held in a vertical or plumb position. The 8Kg hammer is raised until it makes only light contact with the handle and then allowed to free-fall through a distance of 575mm and impact the anvil coupler assembly. The number of blows and corresponding penetrations are recorded. The depth of penetration is taken as 300mm.

DCP Test is conducted on geotextile reinforced and unreinforced sections of each pavement. Photograph of testing using DCP apparatus is shown in figure 5.

Fig: 5 Photograph of the DCP

4. RESULTS AND DISCUSSION

DCP test is conducted on the pavements at an interval of maximum 50m. Depth of penetration is taken as 300mm and the penetration values obtained is plotted with the number of blows and are shown in the figure 6 to figure 11

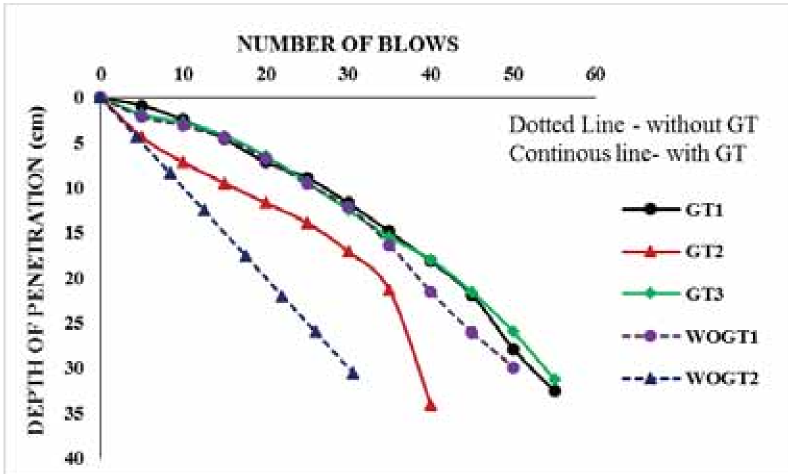


Fig:6 Penetration/blow for road 1

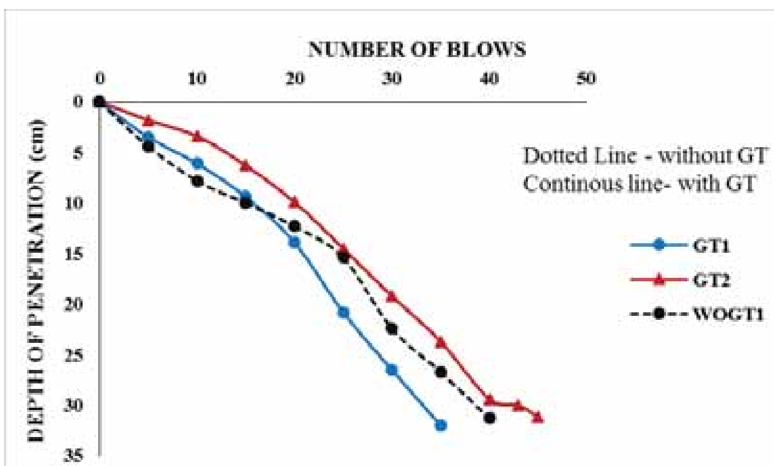


Fig: 7 Penetration/blow for road 2

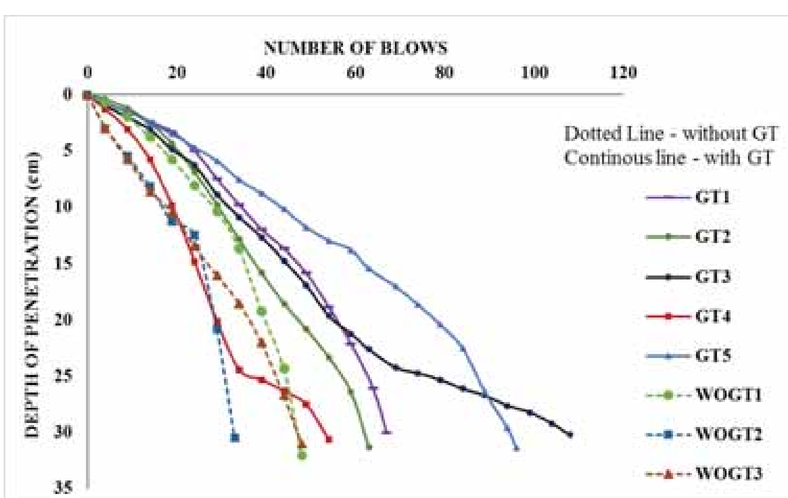


Fig: 8 Penetration/blow for road 3

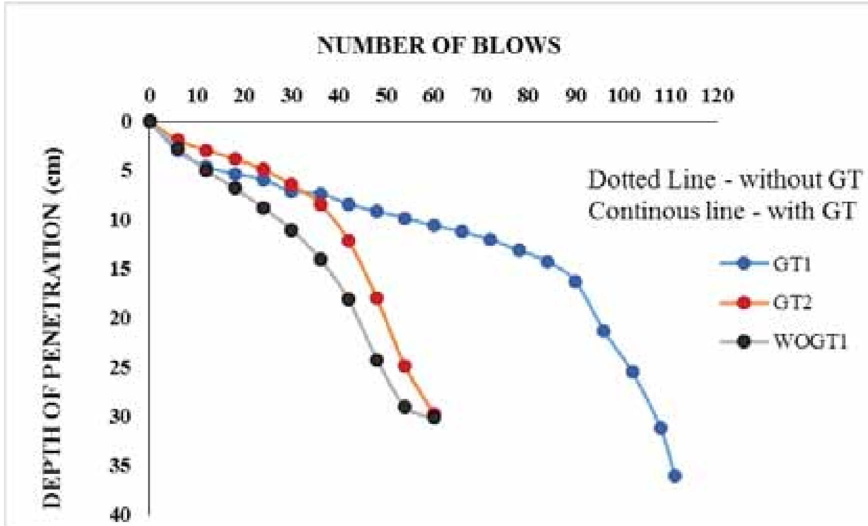


Fig: 9 Penetration/blow of road 4

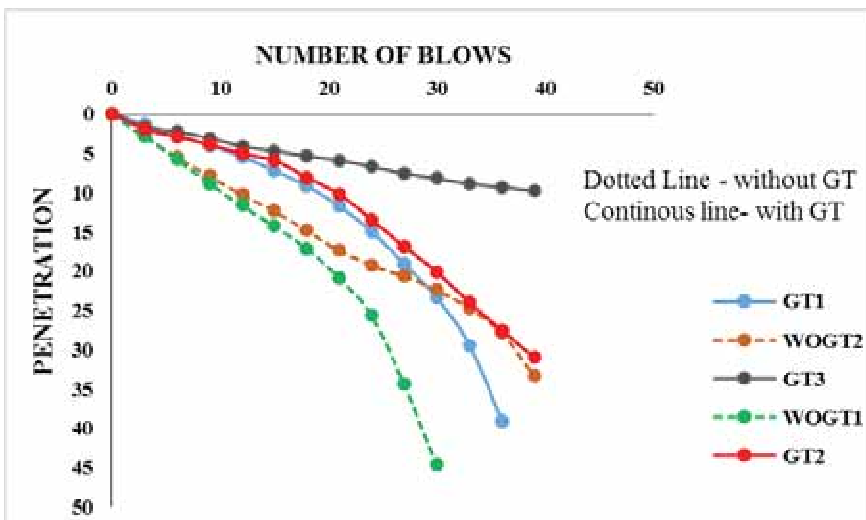


Fig: 10 Penetration/blow of road 5

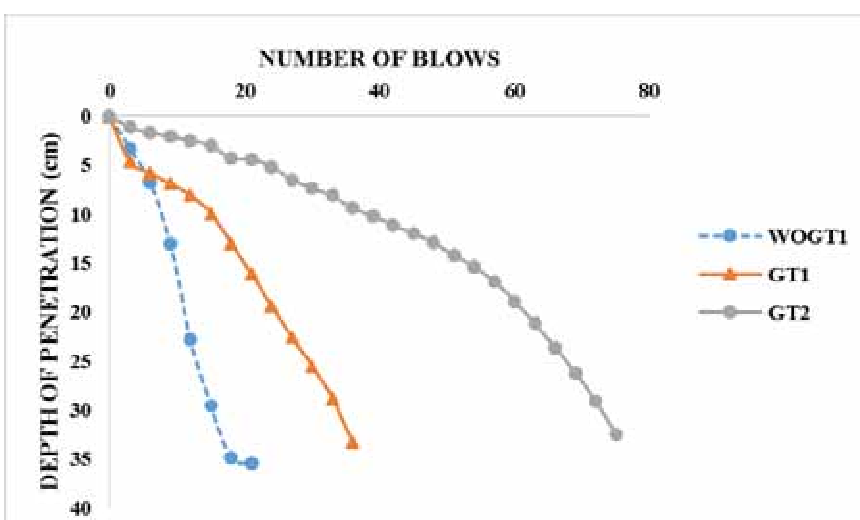


Fig: 11 Penetration/blow of road 5

Penetration index for all the roads are calculated and is taken as the slope of number of blows vs penetration curve. It is given in Table 3

Table 3 DCP Indices (Penetrations per blow) of 6 Pavements

Average penetration in mm/blow											
Road 1		Road 2		Road 3		Road 4		Road 5		Road 6	
GT	WOGT	GT	WOGT	GT	WOGT	GT	WOGT	GT	WOGT	GT	WOGT
0.63	0.75	0.69	0.76	0.42	0.67	0.33	0.52	0.69	0.95	0.62	1.92

It can be seen that all geotextile reinforced sections required higher number of blows for penetrating of 30cm depth of subgrade than that of unreinforced section. Therefore it can be concluded that there is an increase in the strength of pavement in the geotextile reinforced section even after five years of continuous use.

Visual Evaluation

The performances were studied based on visual examinations by noting Alligator Cracking, Block Cracking, Potholes, ravelling, stripping, and edge breaking. It can also be seen that the performance is better for coir reinforced pavements. Visual examination shows that the reinforced road is subjected to less deformations and distresses than unreinforced road.

Durability of Coir Geotextiles

The coir geotextiles were laid during 2011 in AttukalPampadi Road in Trivandrum district. While excavating the pavement for conducting field California Bearing Test during June 2016, it could be seen that the coir geotextiles were remaining as such. Photographs of excavation and the coir geotextiles are shown in Figure 12.

Fig: 12 Extracted Coir Geotextiles

1. CONCLUSION

In this paper, findings of condition survey are evaluated and the results of DCP test of six geotextile reinforced pavement sections are compared with unreinforced sections. It can be seen that the pavement remained functionally stable even after five years of service without any visible distresses compared to unreinforced sections. Coir Geotextiles remain in ground even after five years.

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COIR GEOTEXTILE - A SUSTAINABLE REINFORCING MATERIAL FOR PAVEMENT CONSTRUCTION

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1. INTRODUCTION

One of the major problems faced by roadway engineers in pavement construction is soft soil, which do not possess sufficient strength to support wheel loads imposed upon them, either in construction or during the service life. Pavement constructed over this soft soil demand higher thickness of granular materials resulting in higher cost of construction. Attempts to reduce the thickness of pavement layer to make the construction economic will lead to early failure of pavement which in turn will make the road unserviceable within a short period after construction. This condition may be further worsening, if supplemented with poor or no drainage.

Geotextiles offer significant potential benefit when used as reinforcement in pavement construction. It increases the stability and improves the performance of soft subgrade soils primarily by separating the sub base from subgrade. Placing geotextile at subgrade - sub base or sub base - base interface can enhance the subgrade restraint. Natural geotextiles made of coconut fibre (coir), jute fibre, sisal etc. can be used an alternative to polymeric geotextile materials. Natural fibres are less costly which make it a better choice compared to synthetic fibres.

Reinforcing the sub grade using coir fabrics helps to distribute the load over a wider area and results in enhanced bearing capacity and reduced settlement. This would result in a reduction in the overall thickness of road structure and earth work when it is used as a membrane between the subgrade and the overlying thin granular sub base layer. For unstable and wet subgrade, a coir fabric appears to provide satisfactory solution to stability and drainage problems.

2. COIR GEOTEXTILES FOR STRENGTHENING SOFT SOIL SUBGRADE

Coir is a 100% organic naturally occurring fibre, from a renewable source obtained from coconut husk. Naturally resistant to rot, moulds and moisture, it needs no chemical treatment. Hard and strong, it can be spun and woven into mats. Geotextile made of coir are ideally suited for low cost applications because coir is available in our country in abundance at a very low price compared to other synthetic geotextiles. These geotextile can be applied in the construction of unpaved roads where they can effectively serve the purposes of reinforcement, separation, filtration and drainage.

Coir geotextiles are found to last for as long four to six years within the soil environment depending on the physical and chemical properties of the soil. When used as reinforcement, the coir layers can share the load with soil until its degradation thus increasing the load bearing capacity of the subgrades. When coir geotextiles are used, they also serve as good separators and drainage filters.

In many instances, the strength of subgrade soil increases in course of time as the soil undergoes consolidation induced by the traffic loads. At this stage, the subgrade may be strong enough to support the loads on its own without the necessity for reinforcement. For such applications, where the strength of subgrade increases with elapsed time, the natural reinforcement products are extremely suitable. After the degradation of the coir geotextiles, the organic skeleton remains in place in compressed form which will act as a filter cake keeping the moisture content of the subgrade soil constant.

3. PRESENT STATUS

In spite of having adequate provision in the codes for the use of alternate materials and methods of construction, the use of natural geotextiles are seldom adopted in actual practice in most of the rural road works. The probable reasons for most of our road engineers adopting only the conventional materials and methods of construction and not the alternatives may be:

a. Lack of knowledge or know-how for adopting the new materials and techniques.

b. Fear of possible pre-mature failures.

c. Non-availability of experienced or skilled workers familiar with such alternate methods.

d. Non-availability of contractors who are willing to take up such works.

e. Lack of self-confidence for trying new techniques.

Hence there is a need to popularize the use of innovative techniques such as use of coir geotextiles for strengthening soft soil subgrades of low volume roads by taking up demonstration projects. Since natural geotextiles products such as coir are from traditional industries and no big corporates are available in the industry, it becomes the responsibility of the Government Agencies to initiate R&D.

4. GEOTEXTILE IN UNPAVED ROADS

Geotextiles offer significant benefit when used in road construction. Geotextiles increase the stability and improve the performance of weak subgrade soils primarily by separating the aggregate from the subgrade. In addition it can provide strength through friction or interlock developed between the aggregate and geotextile. The system performance may also be influenced by secondary functions of filtration and drainage by allowing excess pore water pressure in the subgrade to dissipate into the aggregate base course and in case of poor quality aggregate, through geotextile itself.

Four fundamental reinforcement mechanisms have been identified involving the use of geotextiles in unpaved road construction. These are: a) separation, b) lateral restraint, c) improved bearing capacity, and d) tensioned membrane effect.

Separation

One of the reasons for the failure of roads is migration or mixing of fines from the subgrade to overlying granular layer. High wheel load stresses acting on the road surface constructed on a weak/saturated subgrade, typically results in the mixing of base materials with the subgrade soil. This mixing causes a reduction in the effective thickness of base by reducing the actual modulus of granular base.

Lateral Restraint

Lateral Restraint results from four related mechanisms that combine to provide a better overall performance of pavement. On application of wheel loads at the surface, the materials below the wheels tend to spread out. The shear stress due to the wheel loads generated at the base of the granular layer is absorbed by the geotextiles, thus reducing the lateral strain in the upper granular layer. At the same time, this indicates a slightly more lateral stress in the lower portion of the granular layer. Therefore, the granular layer with a greater modulus spreads the surface load over a wider area, thereby reducing the intensity of vertical stresses and vertical strains. Thus the effective shear stress coming on the subgrade is reduced.

Tensioned Membrane Effect

This was first explained by Giroud (1981) and is applicable to cases where rut depth is more, particularly in unpaved roads. The tension in the highly distorted membrane at the base of an overlying granular layer provides a reaction with a vertical component that supports the wheel load at the surface and confines the soft subgrade below.

5. APPLICATION OF GEOTEXTILE

Separation

In transportation applications, separation refers to the geotextile's role in preventing the intermixing of two adjacent soils. For example, by separating fine subgrade soil from the aggregates of the base course, the geotextile preserves the drainage and the strength characteristics of the aggregate material. The effect of separation is illustrated in Fig. 1.

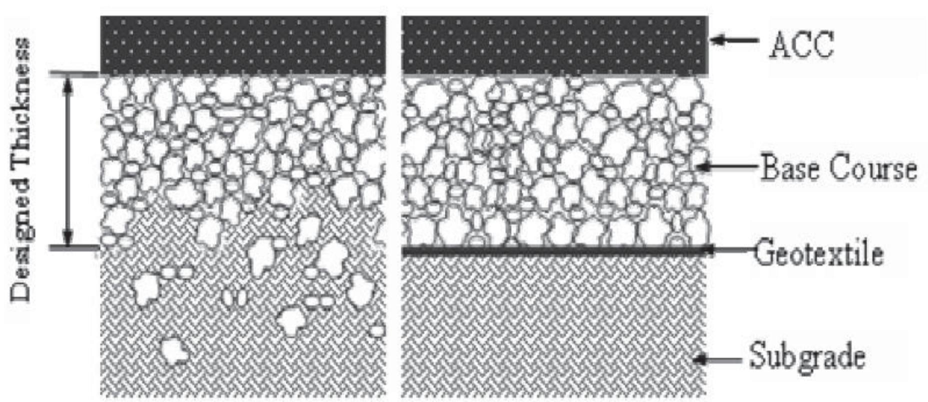

Fig. 1 Geotextile as a separator

Filtration

It is defined as "the equilibrium geotextile-to-soil system that allows for adequate liquid flow with limited soil loss across the plane of the geotextile over a service lifetime". To perform this function, the geotextile needs to satisfy two conflicting requirements: the filter's pore size must be small enough to retain fine soil particles while the geotextile should permit relatively unimpeded flow of water into the drainage media as referred in Fig. 2.

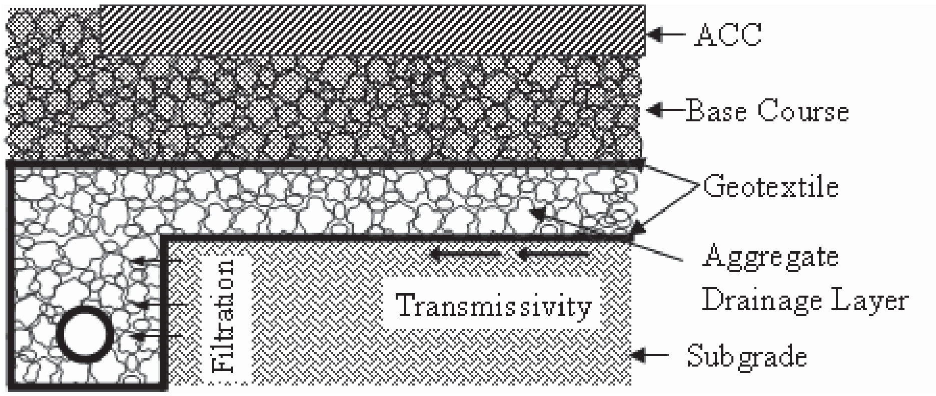

Fig. 2 Filtration and Transmissivity Functions

Drainage (Transmissivity)

This refers to the ability of thick nonwoven geotextile whose three-dimensional structure provides an avenue for flow of water through the plane of the geotextile. Fig. 2 illustrates the Transmissivity function of geotextile. Here the geotextile promotes a lateral flow thereby dissipating the kinetic energy of the capillary rise of ground water.

Reinforcement

This is the synergistic improvement in the total system strength created by the introduction of a geotextile into a soil developed primarily through the following three mechanisms: One, lateral restraint through interfacial friction between geotextile and soil/aggregate. Two, forcing the potential bearing surface failure plane to develop at alternate higher shear strength surface. And three, membrane type of support of the wheel loads.

Sealing Function

A nonwoven geotextile performs this function when impregnated with asphalt or other polymeric mixes rendering it relatively impermeable to both cross-plane and in-plane flow. The classic application of a geotextile as a liquid barrier is paved road rehabilitation, as shown in Fig. 3. Here the nonwoven geotextile is placed on the existing pavement surface following the application of an asphalt tack coat. The geotextile absorbs asphalt to become a waterproofing membrane minimizing vertical flow of water into the pavement structure.

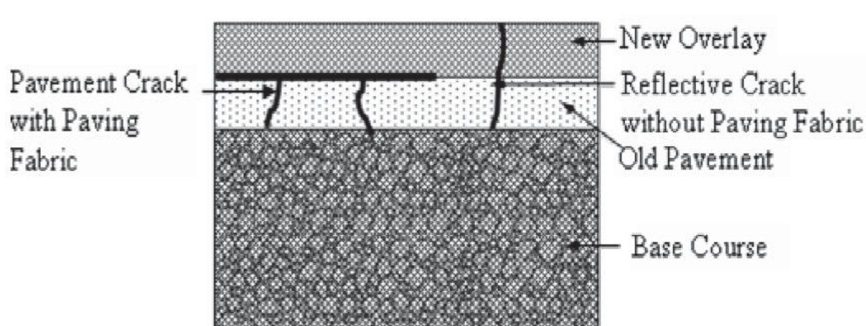

Fig. 3 Sealing Functions

6. LAYING OF COIR GEOTEXTILES

The photos of the process of laying coir geotextile reinforced roads are shown in Plate 1

PLATE 1, LAYING OF COIR GEOTEXTILE REINFORCED ROADS

FINISHED SUBGRADE

LAYING OF COIR GEOTEXTILE

TYING OF COIR GEOTEXTILE ROLLS

COIR GEOTEXTILE READY FOR SUB-BASE

LAYING OF GSB OVER COIR GEOTEXTILE

COMPACTING GSB LAYER WITH ROAD ROLLER

LAYING OF WBM LAYER

COMPACTING WBM LAYER WITH ROAD ROLLER

LAYING OF PREMIX CARPET

FINISHED COIR GEOTEXTILE REINFORCED PAVEMENT

7. CONCLUSIONS AND RECOMMENDATIONS

1. Coir Geotextile has been shown to be effective in reinforcing rural road sections.
2. Pavement Performance studies show that Coir Geotextile reinforced rural road sections produce lesser rut as compared to unreinforced control sections.
3. As compared to the control section, the section reinforced with coir geotextiles have shown improved functional performance in terms of better surface condition, delayed pothole and crack initiation and progression.
4. Coir Geotextile additional reinforcement layer within the subbase other than at the interface of subgrade – subbase produces only a marginal improvement in the performance of the system.
5. Coir in the form of geotextile is advantageous for strengthening of weak soils since it reduces the settlement of soil subgrade.
6. The design of rural roads can be optimized by reducing the thickness of the section with the introduction of coir geotextile.

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Application of Coir Geotextile for Construction of Roads in Rural Areas

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The performance of a road largely depends on properties of subgrade soil and construction material. However, black cotton soil, which is encountered in large area of the country, poses serious problems that include undulations, rutting, potholes and erosion of crust and eventually the road becomes unusable and unserviceable. It becomes necessary in such a situation, either to replace the poor soil to certain depth by good non swelling-shrinking strong soil, or to stabilize the existing poor soil by suitable treatment both the options sometimes become difficult to adopt due to local constraints and therefore more viable, fast solutions needs to be explored. BC soil has very low bearing capacity, high swelling and shrinkage characteristics. Soaked laboratory CBR values of Black Cotton soil is generally found in the range of 2 to 4 percent. Due to very low CBR values, it results in excessive design thickness of pavement. It is needed to improve the engineering behaviour of Black cotton soil high shrinkage and swelling property using coir geotextile . It is very hard when dry, but lose its strength completely when in wet condition. As a result of wetting and drying process, vertical movement takes place in the soil mass leading to failure of pavement, in the form of settlement, heavy depression, cracking and unevenness. In order to improve the performance of roads on such soils, Coir geotextile has a scope as reinforcement. It is expected that with the inclusion of coir geotextile layer below Granular Subbase (GSB) layer would be helpful in restricting the movement of upper pavement layers due to seasonal moisture variation in subgrade expansive, shrinkable soil.

Coir Geotextile (CGT) has prospect of improving the behaviour of poor soils. Recent studies on application of CGT in construction of rural roads on poor subgrade has shown promising results. Coir net is abundantly available as a, renewable resource, readymade material which is cheap and easy to lay in road construction. It acts as reinforcement and improves the strength of the road. Being biodegradable it is environment friendly. This study presents the results of laboratory study conducted on black cotton soil reinforced with a layer of Coir Geotextile of type H2M9 placed at different depths below the loading surface in the California Bearing Ratio (CBR) mould.

Keywords: Black Cotton (BC) soil, Coir Geotextile (CGT), Subgrade, Granular Subbase (GSB), Rural Roads

SELECTION OF TYPE OF COIR GEOTEXTILE FOR EROSION CONTROL APPLICATION

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ABSTRACT

The selection of type of coir geotextiles for erosion control, as of now, is based on experience of the designer. A mathematical model has been developed based on Universal Soil Loss Equation using Fuzzy Logic techniques. The mathematical model developed has been compared with actual field studies conducted in various parts of India. Based on the mathematical model, the type of coir geotextile that best suites for various types of soil and rainfall condition has been tabulated for easy reference.

INTRODUCTION

Soil erosion risk modeling involves various environmental control parameters which are fuzzy inreality. Fuzzy logic model is proved to be more realistic for soil loss prediction(Cohen etal., 2008). Thepresentstudy aims to develop a fuzzy logic model for predicting soil erosion intensity in Kerala,India for different types of soil in various combinations of topography, crop cover, rainfall intensity etc. and thereby simulating the effects of coir geotextile in soil erosion control. The model thus developed can be used to select an appropriate variety of coir geotextile for soil erosion control depending on soil type, topography and rainfall intensity.

In this study focus has been given on the development of soil erosion model based on Universal Soil Loss Equation, its evaluation with actual field result and the simulation on the effect of coir geotextile in erosion control using an integrated tool based on Fuzzy logic in MATLAB.

UNIVERSAL SOIL LOSS EQUATION

The simplest mathematical model for prediction of soil loss is the Universal Soil Loss Equation (USLE) and has been frequently used over the world for estimating sheet and rill erosion. The USLE describes average annual soil loss rates based on estimated and measured input data. The input data is divided into five different factors; rainfall erosivity(R), soil erodibility(K), topography(LS), crop management(C) and conservation practice(P).

The Universal Soil Loss Equation is:

$$A = R*K*LS*C*P$$

COIR GEOTEXTILES

The BIS standard for use of coir geotextiles in erosion control specifies mainly three varieties of woven coir geotextiles. They are based on unit weight viz., 400 gsm, 700 gsm and 900 gsm. This type of classification restricts the use of various types of yarns produced in the industry for geotextile production. In order to compete in the market, especially in erosion control application, the cost of the product will be a controlling parameter. Hence, it will be ideal to use the opening size of the mesh in the geotextile for selection rather than unit weight. Hence in this study only the mesh size, or in geotextile terminology the opening size, of the geotextile has been used. Since both woven and non-woven geotextiles have been proved as effective in controlling the erosion, in this study both the varieties were considered.

The mesh size or opening size of woven geotextiles are represented as;

High Opening size (HO) : Mesh size of 25.4 mm

Medium Opening size (MO) : Mesh size of 12.7 mm

Low Opening size (LO) : Mesh size of 6.35 mm

The opening size of non-woven coir geotextiles are repressented as follows

L4 : Opening size of 3 mm

L3 : Opening size of 1.5 mm

L2 : Opening size of 1 mm

L1 : Opening size of 0.3 mm

FUZZY LOGIC RESULTS

The fuzzy logic model developed in MATLAB has been verified with actual field studies conducted by Kerala Agricultural Unviersity, Vellanikkara and also that by the Kelappaji College of Agriculture Engineering and Technology. The fuzzy logic results agrees with the field results obtained in both the cases, whereas that obtained by computing with Universal Soil Loss Equation was found to vary from the actuals. The results are shown in Fig. 1 and 2.

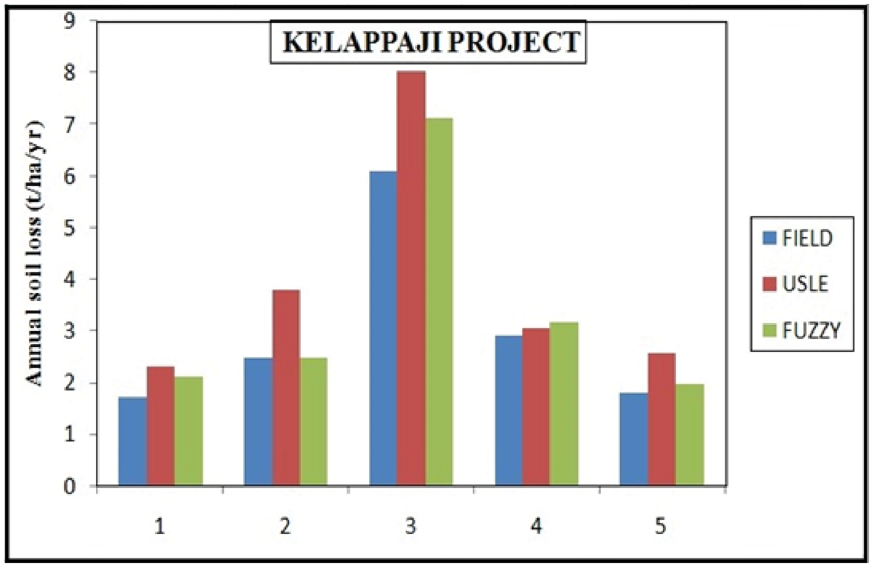

Fig. 1 Comparison of Fuzzy Results with USLE values and actual field results from Kelappaji College of Agricullural Engineering, Kerala

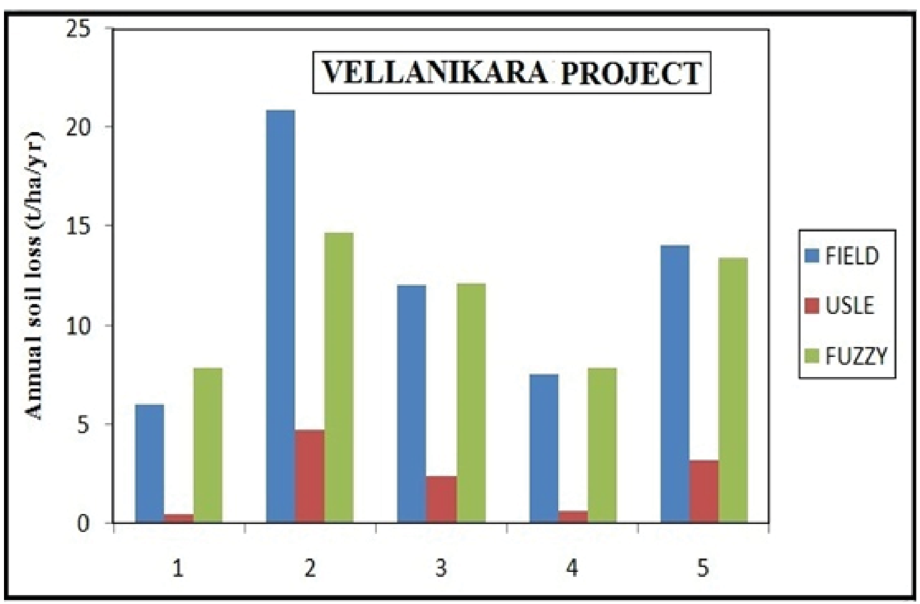

Fig. 2. Comparison of Fuzzy Results with USLE values and actual field results from Agricullural University, Vellanikkara, Kerala.

SELECTION OF COIR GEOTEXTILE

The Fuzzy Logic model thus developed has been extended for the selection of coir geotextile as a crop factor to control the erosion. From the studies the following options were arrived at for selecting the coir geotextiles based on soil type, slope and rainfall intensity. For erosion control, the Annual Soil Loss should be less than or equal to 5 t/ha/year. The geotextile type has been selected for each variety of soil and slope which brings down the Annual Soil Loss quantity to equal or less than 5 t/ha/year.

Table 1 shows the type of coir geotextiles to be used in Kerala with a rainfall intensity of about 220 cm for various soil types.

Table. 1 Type of geotextiles woven/non-woven for Kerala conditions (Rainfall Constant)

SOIL TYPE/ SLOPE	5%	10%	20%	30%	40%
G	HO	HO	LO	L4	L3
GS	HO	MO	L4	L3	L2
S	MO	LO	L3	L1	L1<
LS	MO	L4	L2	L1<	L1<
FS	LO	L3	L1	L1<	L1<
SL	L4	L2	L1<	L1<	L1<
SCL	L4	L2	L1<	L1<	L1<
SC	L4	L2	L1<	L1<	L1<
C	L3	L1	L1<	L1<	L1<
SiC	L3	L1	L1<	L1<	L1<
LS	L3	L1	L1<	L1<	L1<
SiCL	L3	L1	L1<	L1<	L1<
SiL	L2	L1<	L1<	L1<	L1<
Si	L2	L1<	L1<	L1<	L1<

Note: Woven Geotextiles: HO = 25.4 mm; MO = 12.7 mm; LO = 6.35 mm;
Non woven Geotexiles L4 = 3 mm; L3 = 1.5 mm; L2 = 1 mm; L1 = 0.3 mm

GS = Gravelly sand; S = Sand; LS = Loamy Sand; FS = Fine Sand; SL = Sandy Loam; SCL = Sandy Clay Loam; SC = Sandy Clay; C = Clay; SiC = Silty Clay; LS = Loamy Sand; SiCL = Silty Clay Loam; SiL = Silty Loam; Si = Silt.

For places having different intensity of rainfall, the type of geotextiles to be used for various types of soil and slope are presened in Tables 2, 3, 4 and 5.

Table 2: Type of geotextiles woven/non-woven for varying rainfall intensity for 10% Slope

SOIL TYPE / RAINFALL	VL	ML	L	VM	M	MH	H	VH	SH
S	--	--	--	MO	MO	LO	LO	LO	L4
C	HO	MO	L4	L3	L2	L2	L1	L1	L1<
FS	--	HO	MO	LO	L4	L4	L4	L4	L3
SCL	HO	MO	LO	L3	L3	L2	L1	L1<	L1<
SL	--	MO	LO	L4	L3	L3	L2	L2	L1
LS	--	--	HO	MO	LO	LO	L4	L4	L3
SC	HO	MO	LO	L3	L3	L2	L1	L1<	L1<
SiC	HO	LO	L4	L3	L2	L2	L1	L1	L1<
L	MO	LO	L4	L3	L2	L1	L1	L1<	L1<
SiCL	MO	LO	L4	L2	L2	L1	L1	L1<	L1<
SiL	MO	LO	L3	L2	L1	L1	L1<	L1<	L1<
Si	MO	LO	L3	L2	L1	L1	L1<	L1<	L1<
G	--	--	--	--	--	--	HO	HO	LO

Table 3: Type of geotextiles woven/non-woven for varying rainfall intensity for 20% Slope

SOIL TYPE	VL	ML	L	VM	M	MH	H	VH	SH
S	--	MO	LO	L4	L4	L3	L3	L2	L2
C	LO	L3	L2	L1	L1<				
FS	MO	LO	L4	L3	L2	L1	L1<		
SCL	LO	L4	L2	L1	L1<				
SL	MO	L4	L3	L1	L1	L1<			
LS	HO	MO	LO	L4	L3	L3	L2	L1	L1<
SC	LO	L4	L2	L1	L1<				
SiC	LO	L3	L2	L1<					
L	L4	L3	L2	L1<					
SiCL	L4	L3	L1	L1<					
SiL	L4	L2	L1	L1<					
Si	L4	L2	L1	L1<					
G	--	--	--	HO	MO	MO	LO	LO	LO

Table 4: Type of geotextiles woven/non-woven for varying rainfall intensity for 30% Slope

SOIL TYPE	VL	ML	L	VM	M	MH	H	VH	SH
S	MO	LO	L4	L3	L2	L2	L1	L1	L1<
C	L3	L2	L1	L1<					
FS	LO	L4	L2	L1	L1<				
SCL	L4	L2	L1	L1<					
SL	L4	L3	L1	L1<					
LS	MO	LO	L3	L2	L1	L1	L1<		
SC	L4	L2	L1	L1<					
SiC	L3	L1	L1<						
L	L3	L1	L1<						
SiCL	L3	L1	L1<						
SiL	L2	L1	L1<						
Si	L2	L1	L1<						
G	--	--	MO	LO	LO	LO	L4	L3	L3

Table 5: Type of geotextiles woven/non-woven for varying rainfall intensity for 40% Slope

SOIL TYPE	VL	ML	L	VM	M	MH	H	VH	SH
S	MO	LO	L3	L2	L1	L1	L1<		
C	L3	L1	L1<						
FS	LO	L3	L2	L1<					
SCL	L3	L1	L1<						
SL	L3	L2	L1	L1<					
LS	LO	L4	L3	L1	L1<				
SC	L3	L1	L1<						
SiC	L2	L1	L1<						
L	L2	L1<							
SiCL	L2	L1<							
SiL	L1	L1<							
Si	L1	L1<							
G	--	HO	MO	LO	L4	L4	L3	L3	L2

The selection of geotextiles based on rainfall intensity, soil type and slope can be selected based on the above tables. The results shown in the table were cross checked with various site conditions and found that in most of the cases the mesh size selected for application could have been higher than that used in the field. This will reduce the cost of the project.

CONCLUSION

Coir Geotextile selection for erosion control can be made based on their opening size, rather than their unit weight as mentioned in the BIS standard. A Fuzzy logic model has been developed based on Universal Soil Loss Equation using MATLAB software. The model has been verified with actual field studies conducted at various Institutions of Kerala Agricultural University and found that the model represents the field condition very closely. The model has been used to select the coir geotextile based on their opening size, both woven and nonwoven or stiched erosion control blankets. The selected opening size has been verified with material selected in actual field applications and it has been found that in majority of the cases, the opening size could have been increased than that selected. The use of the charts developed from the fuzzy model reduces the cost of erosion control solutions using coir geotextiles.

CHARACTERISTICS OF COIR FIBRE AND ITS APPLICATION AS EROSION CONTROL MATS- AN OVERVIEW

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ABSTRACT

Use of coir based products in erosion control measures have been discussed by various researchers. However, keeping in view of the requirements of promoting sustainable environmental friendly solutions, this paper focuses on the application of engineered coir mats along with the establishment of vegetation in slope protection measures. In addition, characteristics of coir fibre and required specifications of coir geotextile for specific application have been illustrated in detail. Further, few case studies demonstrating the effectiveness of coir based erosion control mats for slope protection measures have been presented.

Key Words: Coir-based erosion control mat, slope protection measures,

1. INTRODUCTION

Soil erosion is one of the prime concerns of the nation as a vast area in India is exposed to erosion due to water and wind. In this context, establishment of sustainable environmental friendly engineered solution for this problem has become the need of the hour. Sustainable vegetation is a key to a balanced ecosystem and provides a permanent solution to accelerated erosion problems. Keeping this in view, application of coir based erosion control mats to establish vegetation and subsequent application in slope protection measures (refer Figure 1) has been presented herein, even though coir fibre has various applications in the field of, filtration, drainage, river bank protection, etc (Beena, 2013; Zachar et al. 2010). Coir fibre is a natural biodegradable product which has unique features that helps to support establishment of sustainable vegetation.

Figure 1: (a) Protection of road embankment (b) Protection of rail embankment

2. Mechanism of erosion control

Establishment of vegetation to mitigate soil erosion has been extensively demonstrated by various researchers (A. Faisal 2010; IRC 56). Subsequently, till the establishment of vegetation, the slope is susceptible to erosion which in turn makes the development of vegetation difficult. In addition, washing away of seeds and seedlings can also occur. In this context, a protective cover on soil is required which can resists soil erosion, retains runoff and facilitates establishment of vegetation on the surface. Subsequently, coir based erosion control mats can be used in such situations which protect the soil beneath until the vegetation takes roots. In addition, high tensile strength of coir fibres protects steep surfaces from heavy flows and debris movement. Eventually, coir being a natural biodegradable material, it degrades and acts as a soil amendment. Once the vegetation is established root system reinforces the soil. Along with protecting the surface, coir based erosion control mats dissipate the energy of raindrop impact, facilitates infiltration of water by improving the porosity of the soil and reduce the velocity of overland flow. Additionally, they help to reduce intense solar radiation, suppress extreme fluctuations of soil temperature, reduce water loss through evaporation and increase soil moisture, which can assist in creating hospitable conditions for plant growth.

3. CHARACTERISTICS AND STANDARD SPECIFICATION OF COIR BASED EROSION CONTROL MATS

3.1. Characteristics of coir fibre

Coir (coconut fibre) is an abundant, versatile, renewable, cheap, and biodegradable lignocellulosic fibre with the following characteristics (S. Tara and H.N.J Reddy, 2011).

a) The fibres are strong and light.
b) The fibres can easily withstand heat.
c) The fibres can withstand salt water.
d) The fibres are moth-proof, resistant to fungi and rot
e) Addition of coconut coir reduces the thermal conductivity and bulk density of the composite specimens
f) It provide excellent insulation against temperature and sound
g) It is the most ductile fibre amongst all natural fibres
h) Coconut fibres are capable of taking strain 4-6 times more than that of other fibres (Refer Figure 2)

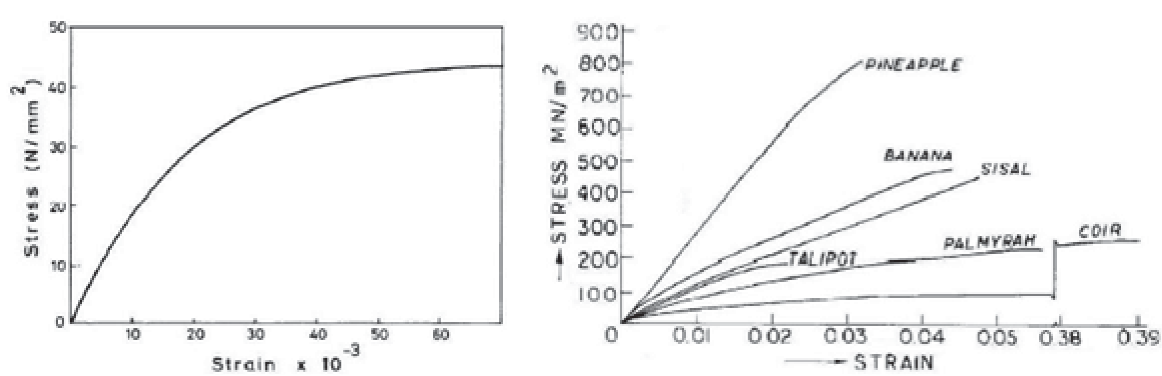

Figure 2: (a) Mean Stress-Strain Curve for coconut fibre (Paramasivam et al. 1984) (b) Stress-Strain Curves of Natural Fibres (Satyanarayana et al. 1990)

Chemical composition of coir and other natural fibres

Coconut fibres contain cellulose, hemi-cellulose and lignin as major composition (refer Table 1). Chemical composition of various natural fibres and coir is illustrated in Table 3. The presence of high lignin content of coir fibre extracted from the husk of coconut (refer Figure 3(a)) helps to provide better performance compared to other natural fibres (Verma et al. 2013) (refer Table 2 and Table 3).

Table 1: Chemical composition of coir fibre

Items	Percentages
Water soluble	5.25%
Pectin and related compounds	3.00%
Hemi-cellulose	0.25%
Lignin	45.84%
Cellulose	43.44%
Ash	2.22%

Table 2: Properties of various fibres (S. Tara and H.N.J Reddy, 2011)

Fibres	Density [g/cm^3]	Tensile strength [N/mm^2]	Modulus of elasticity (GPa)	Moist absorption [%]
Sisal	1370	347-378	15	110
Bamboo	1158	73-505	10-40	145
Coir	1177	95-118	8	93
Jute	1460	400-800	10-30	13
Hemp	1480	550-900	15-45	8

Table 3 : Properties of some vegetable fibres used in India for composites (Verma et al. 2013)

Fibre	Cellulose content (%)	Lignin content (%)	Dia(μm)	Elongation Max. (%)
Banana	64	5	50-250	3.7
Sisal	70	12	50-200	5.1
Pineapple	85	12	20-80	2.8
Coir	37	42	100-450	27
Talipot	68	28	80-800	5.1

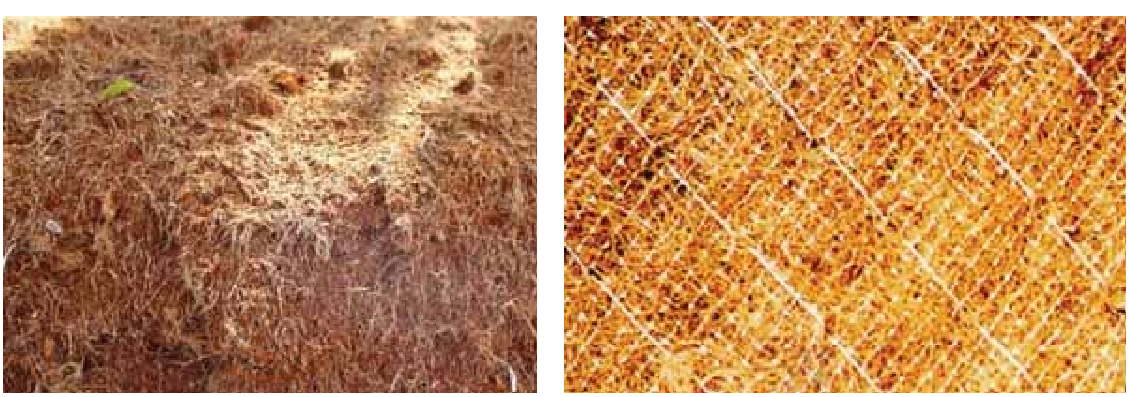

Figure 3: (a) Coconut Husk (Verma et al. 2013) (b) Coir based erosion control mat

3.2. Specifications

As per IRC 56, even though the drapability and water absorption capacity of coir geotextile is less compared to jute geotextile, degradation of coir geotextile is much slower than jute geotextile (expected field life of about 2 to 3 years) which provides protection to the slopes for a longer time than jute nettings. In addition, coir fibres are resistant to saline water (IRC 56). Subsequently, these features help coir-geotextile (Figure 3(b)) to provide an echological niche for a rapid re-establishment of the vegetation cover. Moreover, required strength and other characteristics of coir geotextile have been mentioned in MoRTH 700 as enlisted in Table 4.

Table 4: Typical specifications of Natural Geotextile (MARV*) using Coir (MoRTH 700)

Type of price	Weight (gsm)	Width (cm)	Thickness (mm)	Tensile strength (KN/m)		Elongation at break (%)	Water Holding Capacity (%)	Porometry (°95), Micron
				MD	CD			
Open Mesh fabric	300	120	4.0	5	2.5	20	-	-
Nonwoven Fabric	450	150	4.0	7.5	2.5	30	80	75

3. Case studies

3.1 Stabilization of overburden dumps, Singrauli, Madhyapradesh, India

The Northern Coal Fields, Singrauli in Madhya Pradesh, comprises of many open cast mines, which produces large quantity of waste through its mining activities. Further, continuous deposition of the waste results in creation of large unstable dumps (refer Figure 5(a)) apart from leading to excessive space consumption, causes environment hazards which are of great concern to mining operators owing to the instability associated with the heights and steepness of these dumps.. During monsoon, the unstable slope along the roads to the mines subsides, causing poor access to mines and thus affecting the mining activities. The height of dump ranged from 30m-100m with slope angles of about 40^{o}-60^{o}. Further, the slope was divided into fragments with berms in between. Gabion toe walls were placed at the toe of each slope fragment and multching was done to establish vegetation (refer Figure 5(b) and Figure 6). A non woven geotextile was provided as filter and separator behind Gabion walls. Additionally, french drains at c/c spacing of about 3-5 m were proposed across the slope to ensure drainage and thus to prevent erosion (Roshan et al. 2014). Construction activities of the project started in the year of 2000 and ended in 2007.

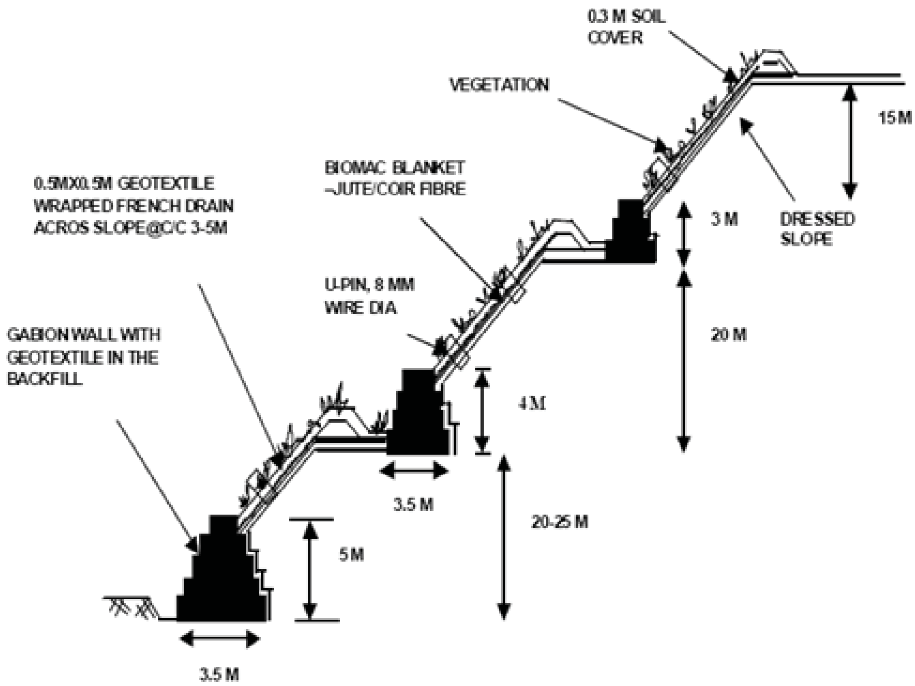

Figure 4: Typical scheme for slope protection provided at Singrauli mines

Figure 5: (a) Initial site condition during construction (b) slope after the growth of vegetation

Figure 6: Vegetated slope (photograph taken in 2016)

3.2 Slope protection measures along muck disposal site of hydroelectric power plant, Shimla, Uttar Pradesh

The present case study is indented to walk through the slope protection measures adopted along a muck disposal site for a hydro electric power plant which is located in Jhakri village, in Shimla, in the state of Uttar Pradesh. The initial site condition is as depicted in Figure 7(a), which is situated at the right bank of the river Satluj. In this context, erosion control measures using coir geotextile which is termed as 'BioMac® CC' (refer Figure 7(b)) along with the establishment of vegetation (refer Figure 10(b) and Figure 11) was adopted in order to avoid falling of the muck into the river, which in turn may affect the river ecology. The site is during the construction is depicted in Figure 9 and Figure 10 (a). BioMac CC is an erosion control blanket manufactured from 100% coconut (coir) fiber. The blanket is covered on the top and bottom with a UV stabilized polypropylene netting, which is stitched together to create an even mat. Also, edges of the mat are rolled and stitched to create a closed edge and prevent unravelling. Laying and anchoring of BioMac CC was done as presented in Figure 8. Installation of BioMac has stated in November 2009 and December 2009.

Figure 7: (a) Initial condition of the slope (b) Coir geotextile

Figure 8: Laying and anchoring of BioMac® CC

Figure 9: Site condition after installation of 'BioMac® CC'

Figure 10: (a) Site condition during installation of 'BioMac® CC' (b) vegetated slope

Figure 11: Vegetated slope

3.3 Slope protection measures adopted for the construction of new airport at Pakyong, Sikkim

Airport authority of India has planned to construct an airport at Pakyong, Sikkim. Further to construct a level platform for runway construction huge cutting of earth and filling of valley was made. Later, to stabilise this fill composite soil reinforced system of height varying from 30 to 74 m was constructed. In addition, Gabion toe wall of around 3 m high (refer Figure 12(a)) was constructed at cutting side to stabilize the slope in conjunction with bioengineering measures adopted using coir-based erosion control mat viz., "BioMac CC" (refer Figure 12(b) and Figure 13). Along with significant design difficulties, presence of steep slopes, heavy rain fall condition and mist, strongly weathered ground conditions with a mixture of sedimentary or metamorphic rock, with some granites, schist, gneiss and a major seismic risk made it more challenging. (A. D. Gharpure et al. 2012). Construction of the slope protection methods suggested started in February 2009 and the work is still in progress.

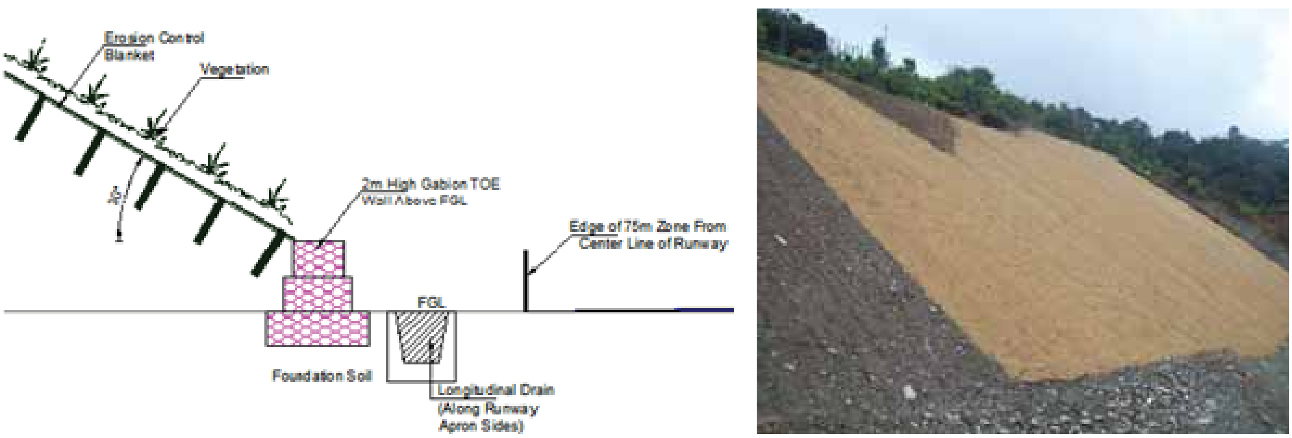

Figure 12: (a) Basic scheme of retaining structures
(b) Cutting slope covered with erosion control mat

Figure 13: Slope protected with 'Biomac CC' (a) after installation (b) 9 months after installation

4 CONCLUSIONS

In the current study an attempt was made to present applications of coir-based erosion control mats along with vegetation in slope protection measures. Even though various biodegradable erosion control mats with natural fibres other than coir are available, due its unique features such as water retention capacity, resistance to saline water and heat, biodegradability, ductile nature, strong fibres due to the presence of high lignin contents etc, coir based erosion control mat is found to be successfully used in various applications. While selecting the bio-engineering measure, soil properties (like particle size analysis, soil pH and soluble salts, cation exchange capacity, presence of micro and macro nutrients, salinity etc.,), climate (temperature, rainfall data), topography, elevation of the site etc are to be considered. In addition to the installation of erosion control mat, suitable bio engineering measures in the form of laying of vegetative soil cover, addition of nutrients and soil amendments, seeds/planting saplings shall be selected judiciously for effective functioning of the overall system . The wide use of erosion control mats in conjunction with other slope protection and/or stabilization measures in various applications of mining industry, and other similar sectors is a silver lining for the coir based erosion control mat for a prosperous future.

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The Coir Geotextiles – Natural Solution to Natures problem

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Soil Bioengineering is a low-tech method of construction using living plants, or plants in combination with non-living organic or inorganic materials, such as coir , jute etc. The living plant becomes in a fairly short period of time the functioning technical component of the system. For instance, in erosion control systems, leaves, stems, and roots shield and bind the substrate to prevent erosion. Systems can also be designed for water quality treatment, sediment accumulation, flood control, or to provide habitat on difficult sites. Eventually, bioengineered constructions become an integral part of the landscape.

Bioengineering techniques aid in the establishments of plant communities on sites where disturbance has caused instability. The practice brings together biological, ecological, and engineering concepts to produce living, functioning systems. Bioengineering utilizes the inherent strengths of a site to protect itself, rather than focussing only on weaknesses. Once established, vegetation becomes self-maintaining. When living plants are impacted by a major force, such as flooding, or conditions are altered by sediment accumulation, plants are capable of regeneration and adaptation. People have taken advantage of the stabilizing properties of plants for hundreds of years, especially in Europe where bioengineering in its simpler forms is a mainstay of construction practices

HISTORIC, ECONOMIC, AND POLITICAL BACKGROUND

The documentation of modern bioengineering can be traced back to the late nineteenth century, but the practice itself is much older, with written references dating back to Julius Caesar himself (Caesar: De Bello Gallico). Soil detachment from hill slopes is primarily driven by rain splash impact. Once detached, sediment becomes available for transport by unconcentrated and concentrated overland flow.

Coir is an abundant natural fibber resource that has drawn the attention of the soil bio engineers. Use of coir geotextiles for erosion and sedimentation control is increasing. Applications of soil bioengineering techniques in erosion and sedimentation control are getting popular, so is the use of coir geotextiles. In durability and strength, coir can be rated as the number one fibre among all types of natural fibre materials used in the soil bio engineering.

The production and export of Coir geotextiles are concentrated in India, Sri Lanka, Vietnam, Philippines etc. In India it is concentrated in Kerala, especially in Alleppey District and in Sri Lanka it is concentrated in Ambamkode area and in Vietnam it is concentrated in Ben Tree Province.

Coir Geotextiles are mainly in two categories, woven and non woven in different weight 400, 700, 900 GSM in woven quality and 300, 450, 550GSM in non woven quality. The width will be 1mtr to 4 mtr and length is 20 mtr to 70 mtr.

Coir Geotextiles are mainly used on road embankments and hill slopes to control soil erosion and to stabilize the slopes. I am attaching herewith few photographs used for the above purpose in Japan, Australia, USA, Europe, India etc. This will give you a fair idea about the effectiveness of Coir Geotextiles in slope protection .

Coir Geo textiles for Environmental Application

Coir Geo textiles is made from coir fibre/yarn extracted from coconut husk either by natural retting or by mechanical process. It is a woven fabric from coir yarn in which the squire mesh (net) gap are positioned at ¼”, ½” and 1”. The netting (mesh) gives the grass plenty of room to grow, at the same time it provides large number of “Check Dams” per square meter of soil surface. The nettings are normally produced on coir handlooms out of 2-ply coir yarn, with a width up to 5 meter and 50-meter length.

Coir geo textiles are used for stabilization of soil through vegetation. These have been used to check the erosion of landscapes and soil slopes as well as protection of banks of river, canal and lakes, road and railway embankment. Reinforcement of mud walls of high velocity streams, bunds, farm and fishponds against erosion and other applications have also been established with experiments and demonstrations. Coir Cell geo textiles is a modified form of te geo textiles which can be effectively used for the reclamation of mine dumping yards.

Coir geo textiles are also used for ground cover or mulch .The term mulch refers to any material which would be decomposed fully or partially over a period of time and serving as nutrient to the vegetation that is being nurtured. The mulch has a short-term role to play and not a long-term role in stabilization. As a ground cover, it reduces the flow velocity of runoff water by forming check dams with the help of net structured strands of coir geo textiles in firm contact with the soil, which absorb the impact of water flow and resist washing down keeping the soil intact. Coir geotextiles provide support to the seeds sown and seedling which could be otherwise easily washed away by water. The strands of the net reduce the wind velocity at the soil surface thereby trap soil particles from being blown away. As mulch, coir geo textiles provide ideal environment for the seeds to germinate and healthy growth of seedling by regulation of soil humidity, temperature and manure and controlling weeds, by protection from direct sunlight and rain.

i) Shoreline stabilization.

ii) Beautification of lakes and ponds.

iii) Plant and tree protection systems.

iv) Landscaping and Golf courses.

v) Sand dune stabilization.

vi) Ski slope and high altitude vegetation.

vii) Protection and re vegetation of waste dumps.

viii) Reinforced soil retaining structures.

ix) Road / Railway / River embankment.

x) Mine site reclamation.

xi) Dams protection.

xii) Bearing capacity improvement for high capacity traffic areas.

xiii) Cuttings and hill slide slopes.
xiv) Irrigation works.
xv) Dam wicks / Table drain outlets.
xvi) Farm and Forestry application.
xvii) Watercourse protection including stream bank protection.
xviii) Storm water channels.
xix) Roof top greening.
xx) Agricultural and horticultural application like mulching, anti weed, vegetative seeding etc.
xxi) Protection from wind erosion.
xxii) Mud wall reinforcement.
xxiv) Separation application in rural roads, railways, parking and storage areas.
xxv) Reinforcement of rural unpaved roads, temporary walls.
xxvi) Providing sub base layer in road pavement.
xxvii) Filtration in road drains and land reclamation.
xxviii) Containment of soil and concrete as temporary shuttering.
xxix) Concrete column curing
xxx) Fly ash dump waste protection and greening
xxxi) Control of shallow mass waste and gully erosion..
xxxii) Wetland environments.
xxxiii) Plant and tree protective systems.
xxxiv) Agri and Horti engineering industry.
xxxv) Soil stabilisation

Types of Coir Bhoovastra

1. Open Weave Coir Bhoovastra

Open Weave Coir Bhoovastra is a net fabric woven from coir yarn. Open Weave Coir Bhoovastra is biodegradable, absorb moisture equal to its own weight and conserved moisture in soil which is sufficient for the growth of vegetation.

Open Weave Coir Bhoovastra have been found ideal geo textile for sloppy land which may lead to riling and gulling. In such slopes, open Weave Coir Bhoovastra provides adequate protection .Coir bhoovastra finds applications in erosion of cut slopes of railways, road, approaches of bridges, canal and drainage bank, bank of river, ponds, lakes, hill slopes and terraces requiring surface stabilisation, reclamation of mine spoil heaps and sand dune stabilisation.

The Open Weave Coir Bhoovastra initially holds the ground for seeds and seedling and provides a mechanical support against water erosion helps the germination of seeds of better and growth of the plants conserving moisture and adds organic matter to the soil after degradation. In areas where vegetation is poor or takes longer time for establishment, Open Weave Coir Bhoovastra can hold the soil together for a longer period of time in comparison to other natural fibres.

2. Geo rolls and Vegetation Fascines

These are mainly used for the stabilization and vegetation of sites marked by steepness or high exposure to waves and currents causing instability. Geo rolls or vegetation fascines are construction modules characterized by a compact roll of coir web covered by exterior coir mesh netting making it strong and flexible. Their configuration and density help them to maintain form without losing material and promote plant growth as well as microbial activity. In areas where there is a constant flow of water, they facilitate new channel alignment. In standing water they initiate sedimentation, facilitate vegetation and dissipate induced wave energy. Geo rolls collect and hold mineral and organic particles, provide a physically stable substrate for root growth and gradually bio-degrade to leave a self sustaining erosion control system. The interior of the geo rolls consist of 100% coir fibre webs cross-lapped or air laid, followed by needle punching or stitch bonding. The fibre density is greater than or equal to 1000 gsm and the width of 220 mm to 600 mm. The substrate is then rolled into desired diameters.

3. Non-woven Felts.

It is a non-woven fabric made from decorticated coir fibre .The fibre mass is held together by coir threads. The coir non-woven blankets are composed of 100% coir fibre randomly needle punched to the desired degree of compaction. The felts have excellent moisture absorption and retention characteristics and form an ideal medium for plant growth.

Coir needled felt

Coir needled felt is a non woven fabric of various densities made from needle punching of coir fibre. In the manufacturing process, well cleaned coir fibres of good staple length pass through the cleaning machines by pneumatic suction and punched by the needle loom on one side to manufacture felts of different density depending upon punching intensity, needle penetration and thickness. The fibre is mechanically bonded (interlocked) to form a continuous length of sheet. No bonding material is used in the manufacture. It can be manufactured in thickness from 10 mm to 20 mm with a density varying from 500 to 1500 g/sq.m. Coir needled felts are available in blanket forms backed with nets made of jute, polypropylene and polythene also.

4. Cocologs

Cocologs are made from coir fibre bunches under pressed condition in tubular enclosures of knotted coir yarn. They are having a shape similar to a wooden log. They vary in diameter, length and weight. The diameter varies from 30 cm to 50 cm, weight from 60 kg to 180 kg, usually produced with a length of 6 metre. Charcoal is also used intermittently for filling the logs as additional manure for faster growth of plants. Cocologs are mainly used for vulnerable streams, rivers or lake bank to protect scour. The rolls are attached at the edges of the bank and secured by wooden stakes/ pegs. The pegs may be used on alternate sides of the log.

For high embankment areas with variable water level, several Cocolog can be applied as a stack.

5. Coir Fibre Beds (Cocobeds)

Cocobeds are made from coir fibre and coir geo textiles. Coir fibre is sandwiched between two coir geo textiles and stitched together to form a bed or pouch. Cocobeds are produced in different thickness, width and lengths. The thickness varies from 5 cm to 15 cm, width from 60 to 100 cm and length 125 cm to 600 cm.

Relatively steep stream banks can be covered with pre planted Cocobeds. Sediments will be collected and held in Cocobeds, which helps in plant growth and purifies water to a certain extent.

6. Coir Loop Fabric

Coir loop fabric is a product made with loop construction usually manufactured in rolls for use as geo fabric for soil erosion control and soil stabilization.

7. Coir Cell Geo Textiles

Coir Cell Geo Textile is normal Coir Geo Textiles provided with woven pockets for the insertion of seed embedded manure blocks/ coir felt etc. The plant species are selected on the basis of suitability to the climatic conditions of the site. The pockets are woven so as to insert the seed implanted blocks or coir felt at the desired places in the Coir Geo Textiles.

Application of Coir Geo textiles

a) For Soil Erosion Control

Site Preparation:

The slope is prepared, leveled and the soil is tamped to the desired shape by rounding of the tips ensuring uniform contact of the coir geo textiles with soil over the entire area to guide the run off to flow over the net. The ground has to be made free of protruding stones, earth masses etc, but natural budges can be left as it is. Before applying any seedling, the prepared slope needs to be relatively free of weeds, stones, root stumps, rivulets, and gullies, crusting and caking. etc.

Fixation

The open mesh coir geo textiles are laid side by side by overlapping of 15 cm while end to end overlapping of two coir geo textiles is 20cm. The overlapping edges are fixed on the ground with the help of either 15 cm long U-shaped nails or 22 cm long J shaped hooks made of 3 mm iron or steel wire.

The sides, top and bottom of coir geo textiles are anchored into the trenches of 30 cm deep and 15 cm width, free from mud / soil slurry at the sides and the bottom. The U shaped nails or J shaped hooks should be driven at intervals of 50 – 75 cm; along sides and overlapping sections at a distance of 30-50 cm. Wooden bamboo pegs may also be used for fixing the coir geo textiles. The hooks must be at the same level with the ground for smooth water flow over the joint to the next fabric.

Laying

The erosion control blanket is to be laid in a direction of the water flow starting from the top to the bottom. The rolls are to be rolled down the slope and are cut at the end. The Coir Bhoovastra should be laid loosely and evenly. Adjoining coir geo textiles should overlap 15cm or be stitched together.

The top and bottom ends of the Coir Bhoovastra are fixed into slots about 30cm deep, dug into the slope. The slots are filled with soil. The Coir Bhoovastra is pegged using U/J shaped or wooden pegs driven at intervals of 50-75cm, along sides and overlapping sections at a distance of 30-50 cm.

Vegetation & Seeding.

The plant species are selected on the basis of suitability to the climatic conditions of the site. The seeds after germination should take up deep rooting system. After preparing the soil surface, the seeds have to be applied on the surface Coir Bhoovastra to be laid over the seeds almost immediately.

First seeding of grass is done at 10g per sq.metre or alternative planting such as root slips may also be done. For quick coverage, rooted slips of grasses and cuttings of shrubs and trees may be planted through the open spaces between the strands of coir geo textiles after laying. Surface is leveled again by compacting the loose soil.

Monitoring

Close monitoring should be carried out for at least two-season cycle. Displacement of Coir Bhoovastra, if any, is to be noted and watched without disturbing it initially. Fresh Coir Bhoovastra pieces duly stapled on all sides should be applied to overlap torn portions.

b). Sub -base layer in Village / Rural Roads / Reinforcement of Paved Roads

The Coir Bhoovastra of low mesh or coir needled felt can effectively be used for soil stabilization techniques in road construction.

The use of coir geo textiles varieties of 700g (H_2M_5, H_2M_2 & H_2M_8) and 900g ($H_2M_{9)}$ with 1/2 inch mesh as an interface between the sub grade and the sub base increases the strength of the pavement and prevents intermingling of the soil and the granular sub base which improves drainage.

c) Application in the Waste Dumping Yards of Mines

Pockets of variant size and dense per area can be made in the Geo Cell Textiles. The blocks or felt can be inserted at the time of weaving or at the site before application. Size and number of pockets to be provided depends on suitable factors for local natural well growing vegetation. Based on the suitability for thick vegetation the coir pith/ manure /soil etc are mixed and embedded with seeds to make the blocks of coir felt. The Coir Cell Geo Textiles can be effectively applied on rocky patches and mainly in the wasting dumping yards of the Mines.

K A Baby, SSO(PD)

Coir pith based cyanobacterial biofertilizers (Cyanopith and cyanospray)

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Abstract

Coir pith is a spin off product of coir industry. Due to pentosan-lignin ratio its decomposition in soil is slow. Degradation of coir pith was carried out using cyanobacteria and the obtained products cyanopith (solid) and cyanospray (liquid) were analyzed for its application in field cultivation. Nutritive analysis of cyanopith and biochemical scrutiny of cyanopith and cyanospray was done. Also, the implemented strategy has contributed in prudent management of solid and liquid waste in a valuable way.

Key words: coir pith, cyanobacteria, cyanopith, cyanospray, textile and tannery effluent

Cyanobacteria

Cyanobacteria (Blue green algae) are photosynthetic prokaryotic microorganisms, which are capable of fixing nitrogen, due to the presence of nitrogenase –an oxygen sensitive enzyme. Cyanobacteria, apart from fixing nitrogen, secrete plant growth hormones as secondary metabolites, make nutrient available and improve to growth and yield of crops. The application of ecofriendly cyanobacteria to degrade coir pith with the help of lignolytic enzyme and production of cyanopith biofertilizer which can be used as biofertilizer to improve the crop productivity.

Coir pith degradation

Degradation of coir pith by cyanobacteria has been confirmed as a result of induction of lignolytic enzyme activity on 7^{th} day. During degradation it releases micro and macronutrients along with plant growth promoting substances which are applied for the plants.

Cyanopith and Cyanospray

Degradation of coir pith using cyanobacteria produced brown colored supernatant (cyanospray) and residue (cyanopith). Applications of coir pith based cyanobacterial biofertilizers named cyanopith and cyanospray influence the growth and yield of plants.

Nutritive analysis shows that cyanopith and cyanospray are rich in plant growth regulators and the lignin percentage is reduced in these obtained degraded products derived from coir pith thereby making it an efficient biofertilizers.

Treatment of Textile effluent

Cyanobacteria with coir pith for bioremediation of textile wastewater and application in the growth of plant has been of great interest in recent research. A study was carried out using marine cynobacterium *Oscillatoria subuliformis* with coir pith for the reduction of physiochemical parameters such as BOD, COD and simultaneous removal of heavy metals such as zinc, nickel, mercury , copper , chromium, iron, nitrogen, phosphorous , potassium, manganese in textile dye effluent. The treated effluent was used as foliar spray on the plant *Tagetes erecta*. Decolorization of textile dye effluent by using *Lyngbya* sp. BDU 9001 with coir pith and other agricultural wastes has been carried out.

Treatment of Tannery effluent

Coirpith and cyanobacteria in the tannery effluent had been an ideal absorbent to absorb heavy metals and other minerals. The effect of cyanobacteria along with coirpith on tannery effluent and analysis of the biochemical parameters of treated effluent and degraded coirpith by cyanobacterium *Lyngbya sp.* has been studied.

Field Trials

Coir pith has been used to treat textile effluent at field level. Coir pith based cyanobacteril biofertilizers have been used as basal and foliar application in various plants. Some of them are listed below:

- *Arachis hypogaea* L. (Ground nut)
- *Hibiscus esculentus* L.
- *Raphanus sativus* (Radish)
- *Dolicus biflorus* (Horse gram)
- *Allium cepa* (Onion)
- *Oryza sativa*
- *Hibiscus sabdariffaa*
- *Sesbania aculeate*
- *Cajanus cajan* (Red gram greens)
- *Vigna ungiculata* and *Solanum melongena*
- *Coriandum sativum* L.
- *Solanum nigrum* L. (Black night shade)

Benefits of coir pith for cyanopith and cyanospray

As Production

- Easily available organic material
- The inoculums gets immobilized
- Increase the potential of the inoculums
- Eliminate bacterial contamination because of its high lignin content
- Increase the shelf life of the inoculums

As Biofertilizers

- Non toxic food
- On farm production
- Fertility of soil
- Safe environment
- Employment
- Combined effect
- Bio-pesticide

Organic farming with self-aerated large-scale composted coir pith

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SUMMARY

Organic farming is gaining momentum all over the world because of growing awareness of human health. Organic agricultural practices encourage use of on-farm resources efficiently. The market for organic food and other products grown organically is expanding quite fast the world over. In India, certain states like Sikkim, Kerala, Maharashtra, Tamil Nadu, Pondicherry and Uttarakhand have put more emphasis on organic cultivation. Organic farming becomes sustainable when the consumers are ready to pay high price premiums on such farm produce. In India, since the middle class population is increasing quite fast, the production from organic farming shall be sustainable. Coir pith is a biomass residue generated during the extraction of coir fiber from coconut husk and is a byproduct of the coir manufacturing industry. Coir pith, both in raw as well as in the composted forms, is gaining increased popularity in developed countries for soil conditioning and in horticulture. Cost-effective technologies that address the development of value-added products from coir pith, therefore, become relevant for countries producing coir pith. There are some descriptions in the literature for the composting of coir pith. According to these processes, the pith is composted in a multilayered structure until the height of the heap reaches a maximum of 1 m. Such methods take over a month for completion. A new method was invented which enables faster composting rates. Adoption of this method by farmers practicing organic farming would be benefitted as the composted material shall be cost effective. Moreover, the material shall add soil texture improvement and increased water holding capacity, thereby would be assisting towards increased production. The new and improved aeration facilitated composting method can be practiced by small and medium farmers at their sites to produce the material with much lesser cost.

Introduction

Organic farming is gaining momentum all over the world because of growing awareness of human health. Concomitantly, environmental imbalance created by excessive use of fertilizers, pesticides and hybrid high yielding seeds/cultivars in mono culture is also raising concern. Organic agriculture is practiced aiming at achieving a natural balance in agro eco system which are economically sustainable. Organic agricultural practices encourage use of on-farm resources efficiently in contrast to modern industrial agriculture which is based on excessive utilization of external inputs such as synthetic fertilizers, chemical pesticides, irrigated water, highly mechanical agricultural appliances etc.

Organic farming is a relatively new alternative agricultural system which relies upon fertilizers of organic origin such as the whole spectra of manure, compost and bone meal. Agricultural techniques emphasize on crop rotation and companion planting. For controlling the insect pests, biological pest control, mixed cropping and use of insect predators are practiced. Naturally occurring pesticides are permitted.

Market of organically grown food

The market for organic food and other products grown organically is expanding quite fast which worldwide reached US$ 63 billion in 2012 and nearly 37 million hectares of farmland are organically managed which represents about 0.9% of the total world farmland[1]. The organically managed farmland had also grown at a compounded rate of 8.9% per annum from 2001 onwards[2]. In India, certain states like Sikkim[3,4] , Kerala[5,6] , Maharashtra, Tamil Nadu, Pondicherry and Uttarakhand[7] have put more emphasis on organic cultivation.

Sustainability factors of organic farming

The plant nutrients in organic farming include compost including coir pith compost, farm yard manure, green manure, neem cake, bone meal, fish meal, press mud, biofertilizers, vermicompost, minerals , rock phosphate etc .However, the productivities are typically lower in organic farming when compared with conventional farming. Organic farming is resorted to for other reasons such as soil conservation, better maintenance of biodiversity, absence of chemical pesticides in the farm produce[8] etc. Organic farming becomes sustainable when the consumers are ready to pay high price premiums on the organic farm produce over the prices of conventional farm produce. In India, since the middle class population is increasing[9] quite fast, the production from organic farming shall be sustainable to some extent.

Coir Pith

Coir pith is a biomass residue generated during the extraction of coir fiber from coconut husk and is a byproduct of the coir manufacturing industry. Normally, they are dumped as agricultural waste and become accumulated as a waste product in the form of heaps of coarse and fine dusts. **Figure 1** shows typical coir pith dumps (hillocks) in the southern states of Kerala and Tamil Nadu in India, where such a problem is widely prevalent. It is estimated that

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[1] Helga Willer, Julia Lernoud and Robert Home The World of Organic Agriculture: Statistics & Emerging Trends 2013 Research Institute of Organic Agriculture (FiBL) and the International Federation of Organic Agriculture Movements (IFOAM, 2013), http://www.organic-world.net/fileadmin/documents/yearbook/2013/web-fibl-ifoam-2013-25-34.pdf

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[6] http://www.newindianexpress.com/cities/kochi/CM-Will-Get-Total-Organic-Farming-State-Tag-by-2016/2014/11/07/article2511534.ece

[7] Ramesh P et al Status of organic farming in India, Current Sci, Vol 98,No 9, pp1190-1194 http://www.currentscience.ac.in/Downloads/article_id_098_09_1190_1194_0.pdf

[8] Organic farming. (2016, June 28). In *Wikipedia, The Free Encyclopedia*. Retrieved 15:32, June 30, 2016, from https://en.wikipedia.org/w/index.php?title=Organic_farming&oldid=727340329

[9] Standard of living in India. (2016, June 6). In Wikipedia, The Free Encyclopedia. Retrieved 05:43, July 1, 2016, from https://en.wikipedia.org/w/index.php?title=Standard_of_living_in_India&oldid=723906341

at present there is an accumulated stock of 10×10^6 metric tons of coir pith in the southern states of India[10]. These agricultural wastes have traditionally been disposed of by burning. This burning has resulted in various environmental problems, including carbon deposits as well as the warming of the atmosphere. During the rainy season, the tannins and phenols of the coir pith are leached out into the soil and into the irrigation canals, thereby making agricultural lands unproductive. Moreover, the water pollution caused by such leaching is harmful to the aquatic and soil biological life. Therefore, alternate ways to dispose of coir pith, such as composting, is of critical importance in these areas.

Figure 1: Coir Pith Dump near a coir fiber extraction site in Kerela

Coir pith is a fluffy, light, spongy material with increased water-holding capacity and extremely compressive and has a sizable percentage of combustible matter along with a low ash content. It is essentially a ligno-cellulosic material that decomposes very slowly in soil, because its pentosan/lignin ratio is 1:0.30; the minimum required for moderately fast decomposition in the soil is 1:0.50. It has been reported that coir pith in combination with cow dung gives a considerable amount of biogas[11]. Nearly 7.5 million tonnes of cir pith is available annually from coir industries in India[12].

Coir pith has been found to be an effective substitute for natural peat. The pH of the composted coir pith is close to neutral, while the pH of natural pith is acidic. The electrical conductivity of the composted coir pith drops to 0.23 dS/cm, in comparison to over 0.7 dS/cm for peat moss. Because coir pith is organic in nature, there are some advantages of its use

[10] Reghuvaran A et. al, Biochemical aspects and formation of phenolic compounds by coir pith degraded by Pleurotus sajor caju, Journal of Toxicology and Environmental Health Sciences Vol. 4 (1), pp. 29-36, 5 January, 2012, Available online at http://www.academicjournals.org/JTEHS

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in agriculture.

Coir Pith composting methods

Coir pith when inoculated with a proprietary bioformulation, such as PITHPLUS[13], and enriched with urea shows a definite reduction in lignin and cellulose contents with an increase in total nitrogen and other nutrient elements after a period of 30 days. PITHPLUS as spawn of edible mushroom Pleurotus sajor caju PITHPLUS is derived from Pleurotus sajor caju, which is a fast-growing, edible oyster mushroom, originally found in India and grows naturally on a succulent plant (Euphorbia royleans) in the foothills of the Himalayas. Even though the use of coir pith on the basis of quantities of 10-15 tons/hectare has also been found to improve the physical conditions of soil and the productivity of many field crops, the use of composted coir pith (prepared by using PITHPLUS and urea) provides better material for soil amelioration. Inorganic urea has been substituted with nitrogen fixing bacteria in the composting process and the results of composting are equally encouraging[14]. Use of nitrogen fixing bacteria also enriches the fertility of the soil in a sustainable manner.

Coir pith, both in raw as well as in the composted forms, is gaining increased popularity in developed countries for soil conditioning and in horticulture. Cost-effective technologies that address the development of value-added products from coir pith, therefore, become relevant for countries producing coir pith. There are some descriptions in the literature for the composting of coir pith. According to these processes, the pith is composted in a multilayered structure, where the different pith layers are interspersed with layers of edible PITHPLUS mushroom and urea or nitrogen fixing bacterial concentrate. The assembly is a six-layered arrangement, which is continued until the height of the heap reaches a maximum of 1 m. The moisture in the heap is maintained at 200% by sprinkling water every day. The PITHPLUS composts the coir pith in open air in about 30-45 days until the pith becomes black in color, indicating the composting of the coir pith moving toward completion. The organic manure thus obtained is richer in nitrogen, phosphorus, and potassium.

The method described above, although effective in composting coir pith, suffers from two limitations. First, it takes over a month for composting when the heaps are larger in dimensions.

Second, the height of the coir-pith heap that this process can compost has to be less than 1 m, which results in a large area of land usage for composting, for a given heap of coir pith. Both of these limitations originate because of the absence of a proper aeration system in the heap of the coir pith. The process described above relies on natural aeration, which can be limiting, especially when multilayered heap structures are designed. The lack of a proper flow of air also results in longer composting times. Both of these issues are addressed in this work that has resulted in accelerated composting times and a smaller use of land acreage for

[13] CCRI, http://www.ccriindia.org/Pithplus.html

[14] Reghuvaran A et. al, Substitution of Urea with Fungi and Nitrogen Fixing Bacteria for Composting Coir Pith, Madras Agric. J., 96 (1-6): 144-149, June 2009, https://sites.google.com/site/majmasu/archive/96-1-6

composting. Specifically, we present a simple and improved process for effective composting of coir pith that is rich in both ligno-cellulose and polyphenols. The process enables in situ composting of large heaps of coir pith and thereby eliminates land pollution.

New method for Coir Pith composting

An alternative fast method of composting was developed by us which could be carried out with huge heap heights as in this process the limitation of stack height was eliminated by our design of aerating the heap through our special design, utilizing the principles of differential densities of air and gases under different temperatures and heights. The theoretical basis of the design was that as composting is an oxidative process it would demand excessive quantities of oxygen during the period of composting. The microorganisms in the process consume the substrates and liberate, as end products, large quantities of carbon dioxide. The composting process is exothermic and usually conducted in heaps. As a result of the heap structure, access of oxygen into the bulk of the heap and release of carbon dioxide and heat are slow. These conditions result in the lowering of the rates of composting. We were therefore interested in devices and methods that could accelerate the rates of composting.

The overall biochemical process in composting involves the consumption of substrates by cells to produce additional cell mass and products and is schematized in **Figure 2**. **Figure 2** is described in a very generic way, where there are n different substrates and m different products formed. Usually, in is about 2-5 main substrates, and m is about 3-7 major products. In our case, we have three substrates, namely, the raw coir pith (before composting), urea and calcium carbonate, and five major products that include depolymerized lignins, oxidized polyphenols, lignin-carbohydrate complexes, laccase enzymes, and dead microbes, including various minerals enriched in the available form.

Overall biochemical reaction of composting and rate of product formation

$$\underbrace{n_1\, CH_\alpha O_\beta N_\delta}_{\textbf{Cell Mass}} + \underbrace{aCH_xO_y}_{\textbf{Carbohydrates}} + \underbrace{b\, H_lO_mN_n}_{\textbf{Nitrogen source}} + \underbrace{cO_2}_{\textbf{Oxygen}}$$

Rate of forward reaction (r1) ↓ **k (Forward reaction rate constant)**

$$n_2\, CH_\alpha O_\beta N_\delta + a' CH_\gamma O_\varepsilon + b' H_uO_vN_w + dCO_2 + eH_2O \qquad \text{(Eq. 1)}$$

, where n_1 **,** n_2 **,** a, a’, b, b’, c, d and e are the stoichiometric coefficients of the reaction. From Eq. 1, the rate of product formation $[CH_\gamma O_\varepsilon]$ follows as under:

$$r1 = d/dt.\ [CH_\gamma O_\varepsilon] = \mathbf{k}\ [CH_\alpha O_\beta N_\delta]^{n1}.\ [CH_xO_y]^a.\ [H_lO_mN_n]^b.[O_2]^c \qquad \text{(Eq. 2)}$$

Figure 2: Schematic biological reaction during composting

The above equation (Eq. 2) implies that the rate of composting varies directly as the formation and concentration of cell mass [$CH_{\alpha}O_{\beta}N_{\delta}$], the concentration of the substrates rich in carbon and nitrogen and also the concentration of oxygen. Since the formation of cell mass [$CH_{\alpha}O_{\beta}N_{\delta}$] is known to be pH dependent and is optimum at neutral pH, we endeavored to create conditions so that the pH of the composting mass remains within the neutral range. We supplemented the composting mass with adequate amount of powdered calcium carbonate to facilitate the neutralization of the composted mass in case acidic conditions are created. We also supplemented with adequate quantities of nitrogen-rich substrates like Urea or any other nitrogen-enriching substrate/substances that there is no dearth of adequate nitrogen source to the microbes. The composting mass is already very rich in carbon substrates and the initial C:N ratio of the mass is usually 100 or above.
To write the overall macroscopic balance, it is useful to represent the substrates, products, and cells in terms of their elemental constitution. For the biochemical process considered in our work, the different substrates can be categorized into two types, namely, a carbon-rich substrate that will be represented by CH_xO_y and a nitrogen-rich substrate that will be represented by $H_lO_mN_n$. The cells convert these substrates into products, represented by $CH_{\gamma}O_{\varepsilon}$ and $H_uO_vN_w$, liberating CO2 and H2O in the process. The cell material will be represented as $CH_{\alpha}O_{\beta}N_{\delta}$. This definition is based on 1g of carbon atoms in the cell and is a convenient representation for a number of microorganisms.

Two experimental programs were carried out in this study. The first experimental program involved the design and construction of an improved aeration system embedded within the heap structure of the compost and its successful demonstration in composting a pilot-scale coir pith heap. This experimental program was carried out on the premises of the Central Coir Research Institute (CCRI) in the southern state of Kerala in India. The second experimental program was a follow up to this pilot-scale demonstration in a real field study for composting a large coir pith hillock located at Thanneermukkom in the Alleppey district of Kerala, India. The design based on the pilot-scale study was scaled up for this demonstration in composting the coir pith hillock. Our design is based on a schematic concept as depicted in **Figure 3.**

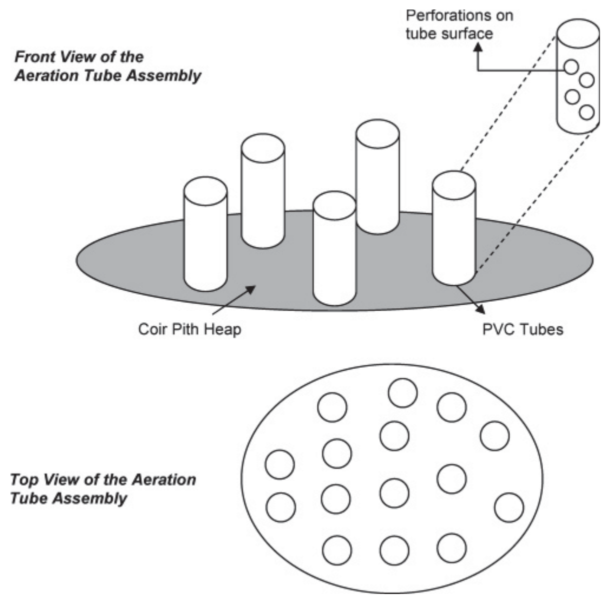


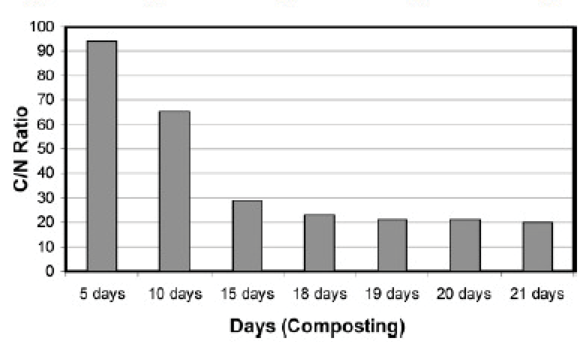
Figure 3: Schematic view of the aeration assembly of our design

Our design provides a system of aeration within the multilayers of the coir-pith heap that enables the inflow of an increased quantity of oxygen to the lignolytic microorganisms. The system of aeration comprises a number of perforated polyvinyl chloride (PVC) pipes, because they are lightweight and recalcitrant to corrosion. The pipes used for the experiment were of an appropriate diameter of 100 mm and were embedded into the heap, equally spaced from each other, at a distance of 60 cm from each other. Each PVC pipe has a large number of perforations with a diameter of 6-10 mm, all over its curved surface, to allow uninterrupted free inflow of air and to provide an outlet for the carbon dioxide and dissipation of the heat generated during composting, through convection.

The results of our study with the improved aerator assembly are shown in **Table 1**.

Table 1. Results of a Raised Platform Composting with an Improved Aeration System

	5 days	10 days	15 days	18 days	19 days	20 days	21 days
nitrogen (%)	0.31	0.42	0.92	1.13	1.17	1.21	1.24
phosphorus (%)	0.02	0.028	0.03	0.04	0.05	0.054	0.055
potassium (%)	0.79	0.85	0.97	1.12	1.16	1.16	1.16
organic carbon (%)	29	27.5	26.9	25.3	25.1	24.9	24.9
pH	5.9	6.1	6.3	6.3	6.3	6.5	6.5
electrical conductivity (dS/cm)	0.71	0.42	0.31	0.29	0.27	0.23	0.23
C/N ratio	94	65	29	23	21	21	20



The table shows the rate of change of the C/N ratio in the coir pith as a function of the number of composting days. The rate of compositing is rapid during the first 5-15 days, decreasing from an initial C/N ratio of 112:1 to 29:1 at the end of 15 days, and almost follows a first-order kinetic rate. After 15 days, the rate gradually begins to plateau, with the composting becoming complete in around 21 days. The change in nitrogen, phosphorus, potassium, organic carbon, pH, and electrical conductivity are also shown during this composting period.

To contrast the rate of composting in our new design against the conventional method, a control composting experiment using the conventional method was also carried out. The layers of pith were placed in multilayered structure as shown below in **Figure 4.**

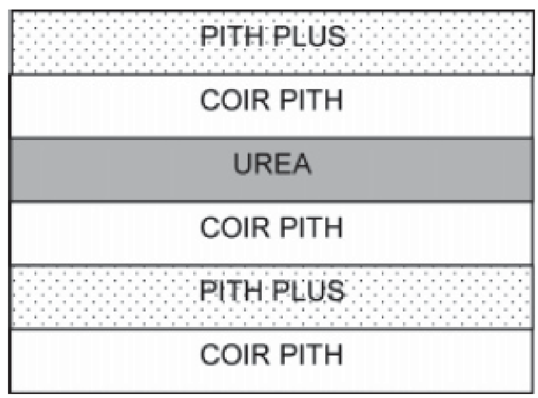


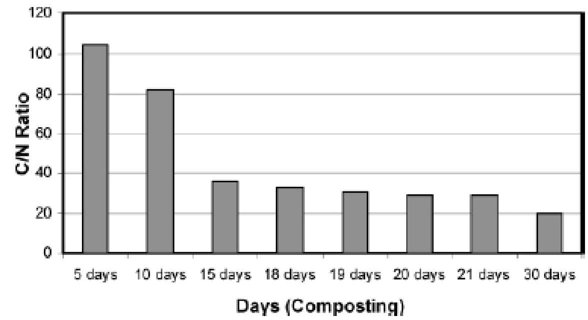
Figure 4: Multi-layer composting method usually practiced

In the above multi-layer composting experiments, additional materials in the form of inoculums were supplemented with calcium carbonate to the extent of 0.5% of the weight of starting non-composted coir pith. The conventional method has no aerator assembly and relies on natural aeration for the composting process. Further, as per the requirement of the conventional method, the height of the heap was maintained as 1 m.

Table 2 presents the results of the rate of composting using the conventional method.

Table 2. Results of a Conventional Composting Process for the Rate of Composting

	5 days	10 days	15 days	18 days	19 days	20 days	21 days	30 days
nitrogen (%)	0.28	0.34	0.78	0.82	0.87	0.93	0.93	1.06
phosphorus (%)	0.02	0.021	0.025	0.04	0.043	0.043	0.05	0.06
potassium (%)	0.74	0.79	0.81	0.91	0.93	0.94	0.94	1.2
organic carbon (%)	29.3	28.9	28	27.4	27.2	27	26.9	24.9
pH	5.6	5.9	6	6	6.1	6.1	6.1	6.5
electrical conductivity (dS/cm)	0.72	0.49	0.39	0.33	0.31	0.31	0.31	0.23
C/N ratio	105	82	36	33	31	29	29	20



When information in **Table 2** is compared with those in **Table 1**, it is clear that the rate of composting is slower in the conventional method. For instance, after 20 days, the C/N ratio in the conventional method was 29:1 compared to 21:1 for our method.

The process has since been widely practiced for fast composting of coir pith in several coconut producing states of southern India. More details of this technology can be seen elsewhere[15].

Composted Coir Pith use for Organic farming

Exhaustively composted coir pith can be used to improve soil texture. Sandy soils can be made more compact and clayey soil can be made more arable. Use of composted coir pith improves soil aggregation as also the water holding capacity. The composted material contains adequate plant nutrient elements. Its use increases native soil microflora as it contains large quantities of humic materials. In agricultural soil, up to 5 tonnes of coir compost can be used per hectare of land. The new and improved aeration facilitated composting method can be practiced by small and medium farmers at their sites to produce the material with much lesser cost. Presently however, coir pith has not yet been extensively used[16] due to inadequate knowledge in composting the material. The Carbon to Nitrogen ratio cannot be reduced to acceptable limits unless proper innoculm and nutrients are utilized in the process. Moreover, the need for providing adequate oxygen during the process of composting is not fully understood by the practitioners and therefore the composted material has considerable residual lignin content. By proper use of processes and innoculum along with more aeration it is possible to obtain high quality composted coir pith, which can be used gainfully in organic farming practices.

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[16] Joshi E et. al, Coir Compost: A source of plant nutrient in Organic Farming, Popular Kheti Volume -1, Issue-4 (October-December), 2013, https://www.researchgate.net/publication/265378637_Coir_Compost_A_Source_of_Plant_Nutrient_in_Organic_Farming

Potential of biocomposting of coir pith using PITHPLUS substituting organic supplements alternate to Urea for Agri/Horti end uses

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Abstract

Coir pith is obtained from coconut husk during the process of extraction of coir fiber. Its demand is steadily increasing for horticultural purposes as a mulch material and soil conditioner. The pith has low density [0.2gm/cc] which makes it suitable for nurseries as a potting media. The coir pith also finds use in the field of geotechnical applications like erosion control blankets. Although raw coir pith has a high water holding capacity (600-800%), farmers still doesn't accept coir pith easily which is mainly due to wider C:N ratio, presence of soluble tannin related phenolic compounds and its low biodegradability due to high lignin content. An exclusively novel method for accelerating the composting of coir pith hillock was developed at CCRI. Through this technology, the composting of coir pith could be achieved within 21 days and the compost thus produced showed an increased percentage of nitrogen (1.26%), phosphorous (0.06%) and potassium(1.20%) with reduced C: N ratio of 19:1, pH of about 6.9 and Electrical Conductivity of 0.21 millimhos/cm making the compost as a desirable organic manure. Composting will leads to increase its manorial value when the lignin content is reduced. Application of urea for composting of coir pith exerts higher concentration of ammonia in the soil, making it even acidic and retards soil natural fertility. High concentration of urea shows burn potential that will kill the plant roots. To overcome these disadvantages, an alternative cost effective nitrogen supplement needs to be developed as a substitute for urea for composting of coir pith. This paper reports the use of biological sources namely Azolla, *Azotobacter* and *Azospirillum* as an alternate to urea for the degradation of coir pith and immense potential applications of biodegraded coir pith in agri/horti sector.

Keywords: Coir pith, organic manure, biodegradability, phenolic compounds.

1. Introduction

Coir pith is a lignocellulosic biomass as it has got very high percentage of lignin and cellulose and it tends to accumulate in the environment forming hillocks. Lignin polymers are major obstacle to the efficient utilization of lignocellulosic materials in a wide range of industrial processes. Coir pith hillocks during the course of time turn out to be an ecologically unfavorable environment leaching out toxic phenolics into the natural water bodies which are harmful to aquatic life. Lignin in the coir pith has to be degraded so that it can be used as a good base material for application as a manure in agricultural fields. Direct application of coir pith results in reduction of soil microbial population and immobilize soil nitrogen. Therefore biodegradation of coir pith is essential to control the pollution caused by its accumulation (*Warrier and Moudil, 1947*).

Table 1 Chemical composition and physical properties of coir pith

Sl No	Constituents	Unretted coir pith	Retted coir pith
1	Lignin (%)	30	29
2.	Cellulose (%)	26.40	25.10
3	Organic Carbon (%)	29.5	29.0
4	Nitrogen (%)	0.24	0.26
5.	Phosphorous (%)	0.01	0.01
6.	Potassium (%)	0.71	0.76
7	pH	5.4-5.8	5.6-6
8	EC (millimhos/cm)	0.8-1.2	0.3-0.6
9	Salinity (ppt)	1	2-4
10	CEC (Meq / 100 g of sample)	15-20	20-25

Structure of coir pith

Retted and unretted coir pith shows some difference in constituents (Table 1). Coir pith consists of three major constituents – Lignin, cellulose & hemicelluloses. Lignin, an amorphous polymer of phenyl propane surrounds the cellulose in cell wall and cellulose, a polymeric chain of anhydrous glucose units exists mainly in crystalline form. The coir pith is a fluffy, light and spongy material with very high water-holding capacity [up to 800%] (Figure 1). It decomposes very slowly in soil, because its pentosan /lignin ratio is 1:0.3; the minimum required for moderately fast decomposition in the soil is 1: 0.5 (Ghosh *et al*. (2007). About 7.5 x10^6 tons of coir pith is produced annually in India. The coir pith once considered a waste material has been found to be useful for horticultural purposes because of its high water holding capacity. It provides the soil less medium for growth of nursery plants and has been used extensively in various countries for the purpose.

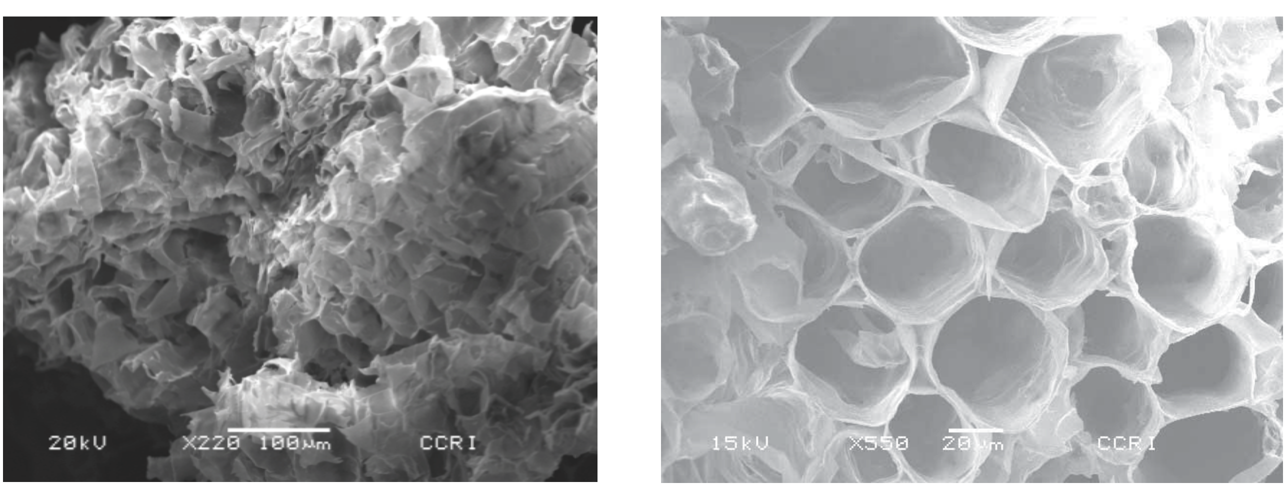


Figure 1. SEM image of coir pith

Lignin is a constituent of the cell walls of almost all dry land plant cell walls. It is the second most abundant natural polymer in the world. It is composed of up to three different phenyl propane monomers viz Coniferyl alcohol, syringyl alcohol and coumaryl alcohol units(Figure 2).

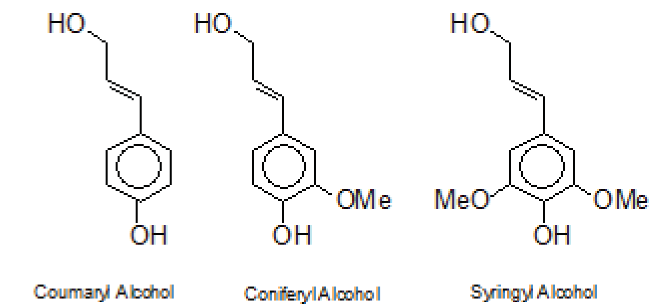


Figure 1: The three phenyl propane monomers in lignin

Lignin and cellulose work together to provide a structural function in plants analogous to that of epoxy resin and glass fibers in a fiberglass boat (Figure 3). The fibrous components, cellulose or glass fibers, are the primary load-bearing elements while the matrix, lignin or epoxy resin, provides stiffness and rigidity. Beyond the structural function, lignin plays several other important biological roles in plants. Because it is much less hydrophilic than cellulose and hemicellulose, it prevents the absorption of water by these polysaccharides in plant cell walls and allows the efficient transport of water in the vascular tissues. Lignin also forms an effective barrier against attack by insects and fungi.

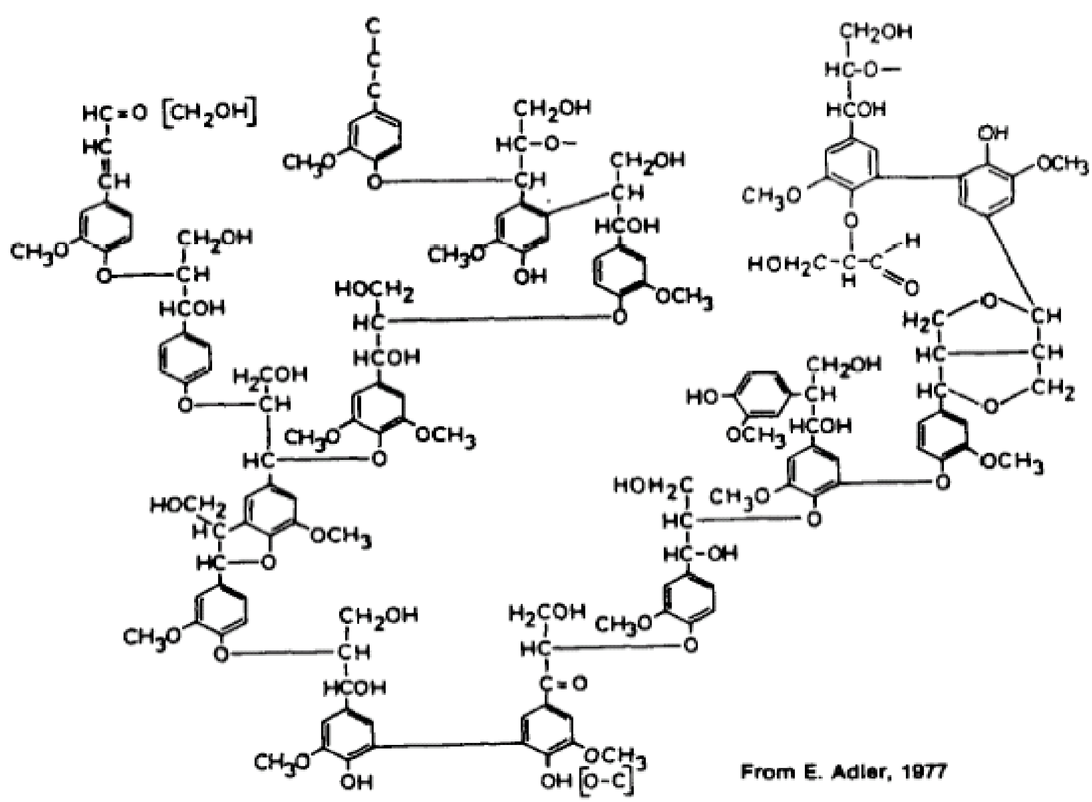


Figure 3. Structure of Lignin

Several experimental studies have been conducted on biodegradation of coir pith using combinations of fungi, bacteria, and actinomycetes which have yielded encouraging results. Composting is the biological conversion of waste material, under controlled conditions, into a hygienic, humus rich, and relatively bio-stable product that conditions soil and nourishes plants. A process of composting has been standardized by Central Coir Research Institute (Coir Board) for preparation of organic manure / fertilizer out of coir pith using urea as nitrogen supplement The manure thus obtained is rich in nitrogen (1.26%), phosphorous (0.06%) and potassium (1.20%) which is essential for plant growth (Venkitaswami, 2003). An exclusively novel method for accelerating the composting of coir pith hillock was also developed at CCRI (*Ghosh et al*., 2007). Through this technology, the composting of coir pith could be achieved within 21 days and the compost thus produced showed an increased percentage of nitrogen (1.25%), phosphorous (0.057%) and potassium(1.18%) with reduced C: N ratio of 19:1, pH of about 6.9 and Electrical Conductivity of 0.21 millimhos/cm making the compost as a desirable organic manure. The principal change brought about in coir pith during composting is the breakdown of lignin which forms the chief constituent (30%) in it.

Composting of coir pith (Conventional method)

Coir pith when inoculated with PITHPLUS, and enriched with urea shows a definite reduction in lignin and cellulose content with an increase in total nitrogen and other nutrient elements after a period of 30 days. PITHPLUS is derived from *Pleurotus sajor caju*, which is a fast-growing, edible mushroom (Bisaria *et al*. (1987). A simple technology for accelerated composting of coir pith has been developed by Coir Board using PITHPLUS, a lignolytic fungus (*Pleurotus sajor caju*) and the composting will be completed in 30 days (Figure 4 a & b). The composted pith is excellent organic manure, with a reduced C/N ratio of 20:1, pH of about 6.9, and electrical conductivity of 0.19 millimhos/cm, making it more desirable soil manure.

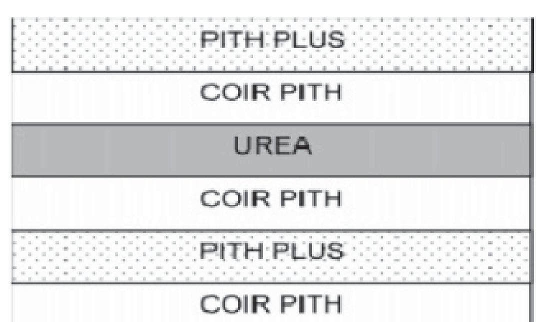


Fig 4 . a, Pithplus b. Sandwiching process of coir pith for composting

Bulk composting of coir pith hillock using perforated PVC pipes

An exclusively novel method for accelerating the composting of coir pith hillock was also developed at CCRI (Ghosh *et al*., 2007). Through this technology, the composting of coir pith could be achieved within 21 days and the compost thus produced showed an increased percentage of nitrogen (1.26%), phosphorous (0.058%) and potassium(1.20%) with reduced C: N ratio of 20:1, pH of about 6.9 and Electrical Conductivity of 0.21 millimhos / cm making the compost as a desirable organic manure. The principal change brought about in coir pith during composting is the breakdown of lignin which forms the chief constituent (30%) in it. Composted coir pith can be applied as an ideal plant nutrient source for all plants.

In order to compost larger quantities of coir pith (say 100 MT or more) would be difficult if we use the conventional method. This can be attributed to the decrease in efficiency of biodegradation due to the lack of aeration for the release of carbon di-oxide produced. The dissipation of heat generated during composting process would also be slower, resulting in rise in the temperature within the bulk of the composting heap. This in turn would destroy the microbial population responsible for the biodegradation and thereby slowing down the same. The composting process would therefore be considerably arrested and would restart only after natural cooling of the composting heap. The new design system provides aeration within the coir pith hillock that enables the inflow of an increased quantity of oxygen for the biodegradation activity of the lignolytic microorganisms. The system comprises 19 numbers of 5 m perforated polyvinyl chloride (PVC) pipes. The pipes used for the trial were of diameter of 100 mm (4") and were embedded in the heap equally spaced from each other over an area of 10 m x 6 m square arranged near the hillock. The perforated pipes are light weight and resistant to corrosion. The pipes are placed vertically with the support of clay bricks and extended 1 meter above the heap. Each pvc pipe has a large number of perforations, all over its curved surface, to allow the uninterrupted free inflow of air and as an outlet for the carbon dioxide and dissipation of the heat generated during composting through convection. The schematic arrangement of PVC pipes over an area of 10 x 6 m is illustrated in Figure 5.

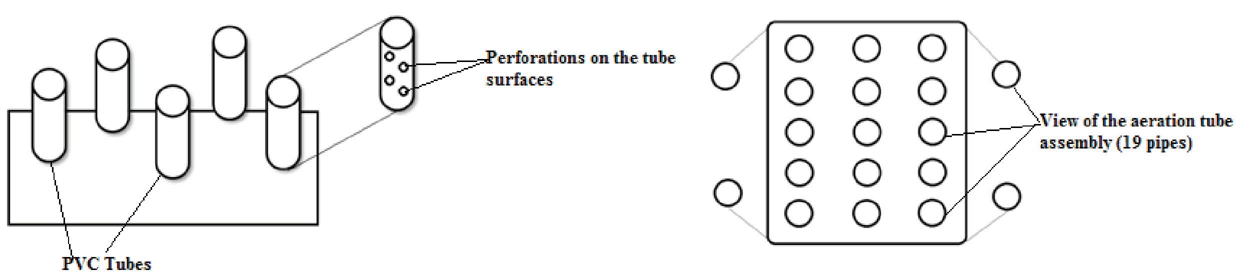


Figure 5: Schematic diagram of aerator tube assembly

Although composting alleviates the problem of pollution by the accumulation of coir pith, urea which is being used as nitrogen source has some disadvantages. Nitrogen fixation is an important source of nitrogen for biological productivity in the environment. Application of urea for composting of coir pith exerts higher concentration of ammonia in the soil making it even acidic and retards soil natural fertility. High concentration of urea shows burn potential that will kill the plant roots. To overcome these disadvantages, an alternative cost effective nitrogen supplement needs to be developed as a substitute for urea for composting of coir pith.

Experimental trials were designed in combination with different biological sources in varying proportions with *Pleurotus sajor caju* so as to develop an alternative to urea for composting of coir pith. The selected natural component *viz*., Azolla is a floating fern and belongs to the family of Azollaceae, rich sources of nitrogen and is cheap, readily available in market as and when required. Azolla contain 5.71% of nitrogen. Azospirillum is a biofertilizer. Both these natural supplements have nitrogen fixation capability. To determine the rate of degradation of lignin in coir pith, mushroom culture was maintained on solid substrate (sorghum) and incubated for 15 days. Further the mushroom used in the present study was inoculated and proliferated along with supplements on coir pith for thirty days to ensure degradation of lignocelluloses. This paper evaluates the potential of use of Azolla and Azospirillum as a substitute for nitrogen during its biodegradation of coir pith by *Pleurotus sajor caju.*

2. Materials and Methods

Culture Inoculum

The white rot Basidiomycetes, *Pleurotus sajor caju* was collected from Central Coir Research Institute (Coir Board), Alleppey, Kerala. The culture was maintained on Potato Dextrose Agar slants, stored at 4 ºC and sub cultured once a month. It was mass cultured on sterilized media consisting of sorghum mixed with 0.2% calcium carbonate as carbon source in polythene bags. Fully grown packets (400 gms) after 15 days of incubation were used for carrying out the experimental study on biodegradation of coir pith.

Coir pith and biological supplements

Coir pith used for carrying out this experiment was collected from a coir defibring unit at Kattukada, Cherthala in Alleppey District of Kerala. The biological nitrogen supplements *viz.,* Azolla was collected from a nearby nursery, Azospirillum from Rice Research Staion,Mankombu.

a. Azolla

Azolla is a floating fern and belongs to the family of Azollaceae which contains an endo-symbiotic microbial community living in the dorsal lobe cavity of the leaves and this association was capable of nitrogen fixation (Figure 6 a). In many countries this has been extensively used as green manure for long term soil fertility. Azolla hosts symbiotic blue green algae, Anabaena azollae, which is responsible for the fixation and assimilation of atmospheric nitrogen (Figure 6 a, b,c & d) . Azolla, in turn, provides the carbon source and favorable environment for the growth and development of the algae. Azolla is easy to cultivate and can be used as an ideal feed for cattle, fish, pigs and poultry, and also is of value as a bio-fertilizer for wetland paddy. Azolla is very rich in proteins, essential amino acids, vitamins (vitamin A, vitamin B12 and Beta- Carotene), growth promoter intermediaries and minerals like calcium, phosphorous, potassium, ferrous, copper, magnesium etc. On a dry weight basis, it contains 25-35 percent protein, 10-15 percent minerals and 7-10 percent of amino acids, bio-active substances and bio-polymers. Its nutrient composition makes it a highly efficient and effective feed for livestock.

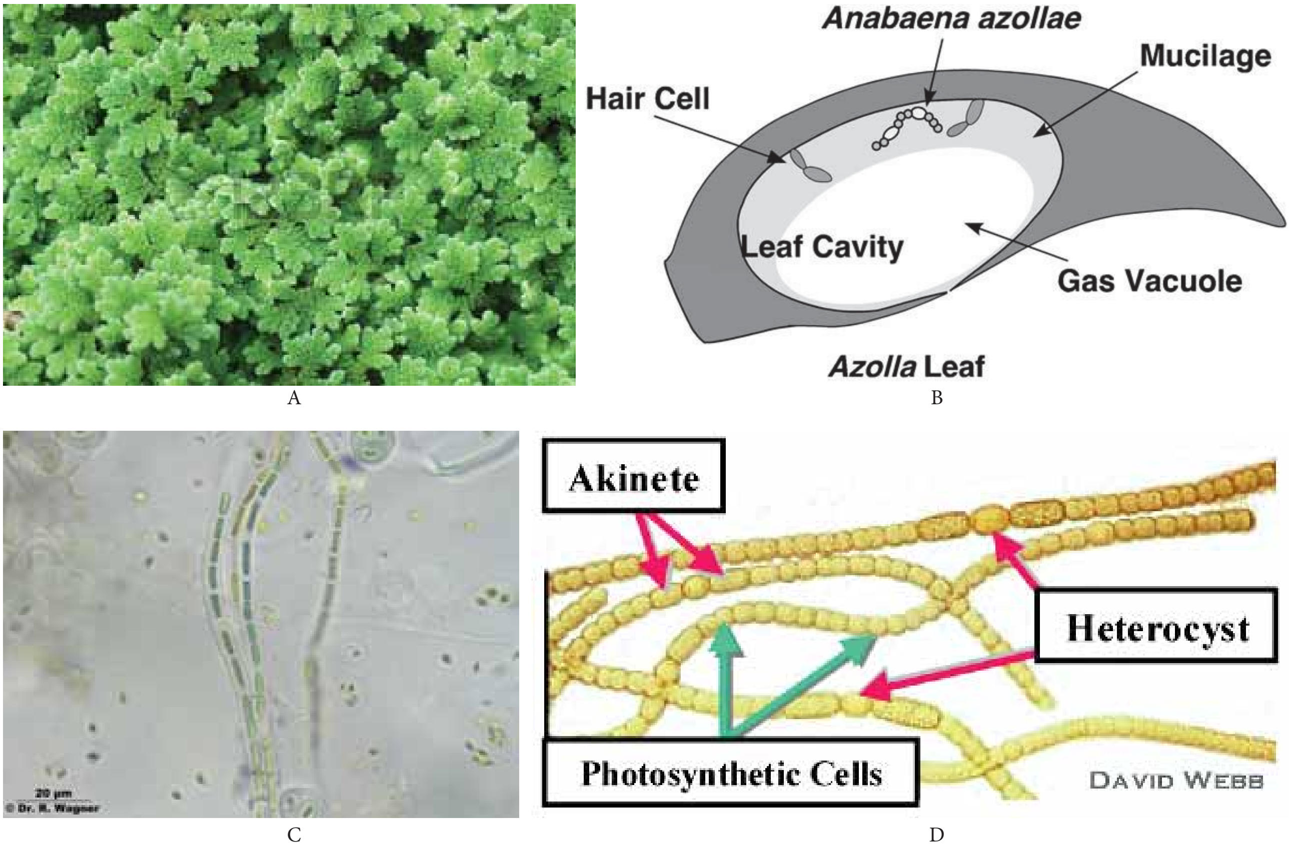


Figure. 6. a. Azolla ; b. Azolla leaf; c Cyanobacteria d. Cyanobacterial filament with heterocyst

Azotobacter vinelandii is gram-negative and an aerobic soil-dwelling organism with a wide variety of metabolic capabilities which include the ability to fix atmospheric nitrogen by converting it to ammonia (Figure 7). Like *Klebsiella pneumoniae* it fixes nitrogen in the free-living state and does not enter into symbioses with plants; a process typified by the symbiosis between members of the genus *Rhizobium* and a variety of leguminous plants. Two features of the biology of *Azotobacter* make it of particular interest to scientists studying the nitrogen fixation process.

Azospirillum brasilense represents the best characterized genus of plant growth-promoting Rhizobacteria (Figure 8). Other free-living diazotrophs repeatedly detected in association with plant roots, include Acetobacter diazotrophicus, Herbaspirillum seropedicae, Azoarcus spp. and Azotobacter. Four aspects of the *Azospirillum*-plant root interaction are highlighted: natural habitat, plant root interaction, nitrogen fixation and biosynthesis of plant growth hormones. Each of these aspects is dealt with in a comparative way. Azospirilla are predominantly surface-colonizing bacteria. *Azospirillum brasilense* is one of the most well-studied plant growth promoting bacteria. It is considered a free-living soil bacterium that has the ability to affect the growth of numerous agricultural crops worldwide through the excretion of various hormones and the bacteria's ability of nitrogen fixation. Many countries use bacterial inoculants containing *A.brasilense* alone or in concert with other plant growth promoting bacteria. Within the phylum of Proteobacteria there are multiple subgroups; *A.brasilense* belongs to the alpha subclass of Proteobacteria and alphaproteobacteria. Newton and Cavins, 2003 studied the nitrogen fixation (acetylene reduction) and ammonia liberation was studied in a facultative heterotrophic Cyanobacterium. Nitrogeneous fertilizers are one of the most widely used chemical fertilizers, as deficiency of nitrogen in the soil often limits crop yields (Sarita *et al*, 2008).

Fig.7 *Azotobacter vinelandii*

Fig.8 Azospirillum brasilense

Culture Conditions

Experiment on biodegradation was carried out by laying coir pith heaps in an open shady place. Coir pith was mounted in 5 kg heaps in triplicate and was substituted with 5%, 10%, 15%, 20% and 25% of biological supplements *viz* Azolla, Azotobacter and azospirillum. An un-inoculated coir pith heap was maintained as control for comparison. The experimental coir pith heaps were allowed to decompose for thirty days. Samples have been drawn periodically from the experimental heaps at regular intervals of 5, 10,15,20,25 and 30 days of composting and analyzed for the biodegradation by studying the physicochemical parameters. The Nitrogen, Phosphorous, Potassium, (NPK) content and C: N ratio of biodegraded coir pith was analyzed as per AOAC methods. The properties viz pH, Electrical Conductivity, Salinity of coir pith were also tested at regular intervals., The rate of coir pith degradation was assessed by estimating the percentage of lignin reduction in the samples drawn, by Klason method.

A significant finding from the foregoing studies reveals that coir pith compost prepared by the addition

Table.2 Nutrient status of raw & coir pith organic manure

Parameter	Raw coir pith	C-POM
Nitrogen (%)	0.26	1.26
Phosphorous (%)	0.01	0.06
Potassium (%)	0.78	1.20
Organic carbon (%)	29.3	24.4
C:N ratio	112:1	19:1
Lignin (%)	30	4.8
Moisture (%)	30	60
pH	5.4	6.9
Salinity (parts per thousand)	3	0
Electrical Conductivity (millimhos / cm)	0.98	0.21

3, Results and Discussion

It has been observed that partial substitution studies of carbon and nitrogen with vegetative sources could result in the vigorous growth of the mushroom accelerating the rate of lignin degradation leading to an increase in the nitrogen, phosphorous and potassium content in coir pith. Application of Azolla as nitrogen source to coir pith resulted in an enhancement of nitrogen to 1.18%, phosphorous to 0.051% and potassium to 1.09 (Figure. 9). Addition of azospirillum an increase in NPK status 1.17%, 0.053% & 1.05% respectively in the biodegraded coir pith after 30 days. Of the different combination trials on coir pith conducted, incorporation of Azolla individually was observed to enhance the NPK in biodegraded pith. The same dosage of Urea, an inorganic chemical nitrogen fertilizer used in composting exhibited an increase of 1.26% of nitrogen in coir pith.

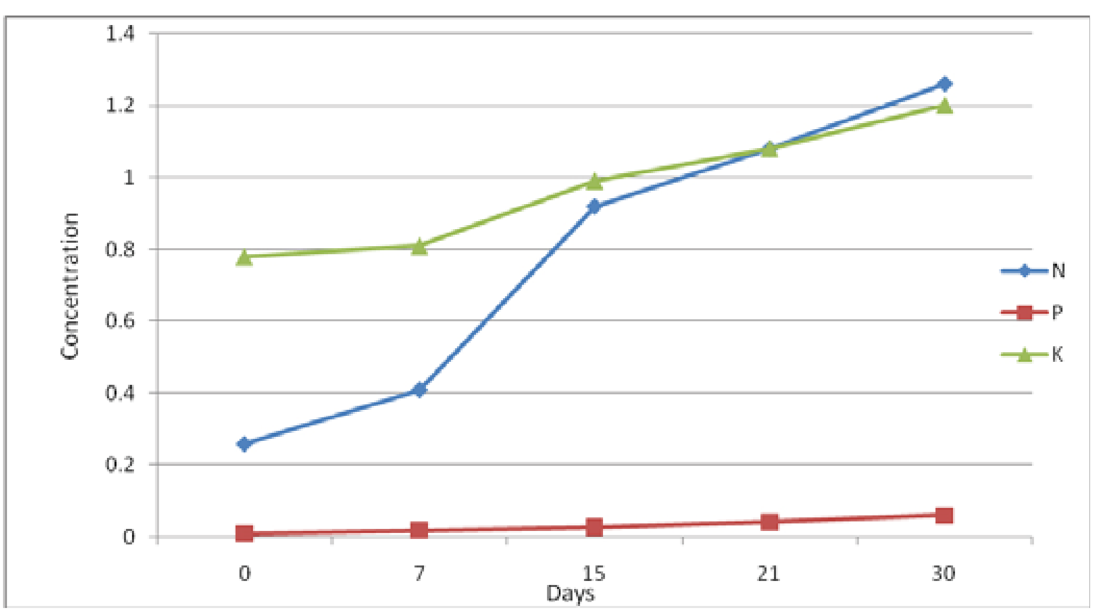
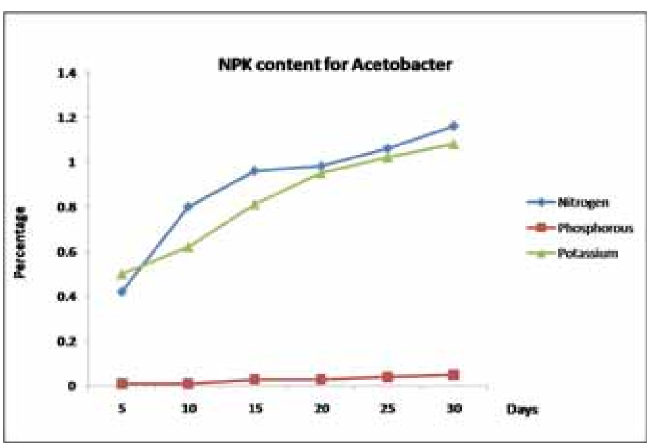


Fig 9. Increasing trend of NPK during coir pith composting

of urea resulted in yielding 1.26% of nitrogen, 0.06% of phosphorous and 1.20% of potassium whereas the new combination of biological sources resulted in enrichment in NPK level to 1.18%, 0.051% and 1.09 by Azolla and 1.17%, 0.053% & 1.05% respectively with *Azospirillum*. Even though the values for NPK are comparatively less in composted coir pith, Urea – the artificial fertilizer could be substituted by addition of new biological supplements viz. Azolla, *Azotobacter* and *Azospirillum* the technology is ecofriendly and cost effective. Hence the new combination of biological sources formulated in the present study is significant.

The combined rather than individual action of microorganisms can enhance the performance and bring about better biodegradation activity. In the present study, use of a basidiomycete fungus. *Pleurotus sajor caju*, which is an edible mushrooms having the ability to degrade coir pith with the addition of nitrogen fixing bacteria like *Azotobacter vinelandii* and *Azospirillum brasilense* can accelerate the degradation of coir pith. The use of these microorganisms brings about definite changes in the Nitrogen, Phosphorous and Potassium contents in the resultant biodegraded coir pith. Biodegraded coir pith composted with *P.sajor caju* in combination with *Azotobacter vinelandii* shows 1.16% nitrogen in 30 day from 0.4% in raw coir pith. Phosphorous content also show enhancement to 0.051% and Potassium have a steep increase to 1.08%. Same trend have been noticed in the case of *Azospirillum brasilense* also. The amount of nitrogen observed was 1.17%, 0.053% (Phosphorous) and 1.09% (Potassium) which was also higher than raw coir pith. From the study it is also clear that *Pleurotus sajor caju* is more efficient in combination with nitrogen fixing bacteria for the degradation of coir pith. It can also solve the disposal problem of coir pith which accumulates in the coir fibre extraction units leading to abatement of land pollution.



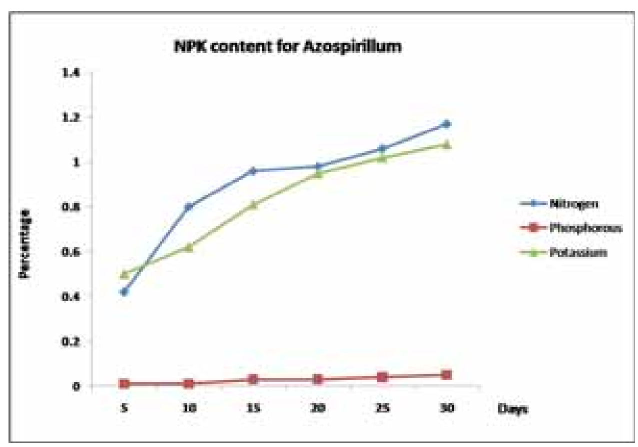


Figure 10. Increasing trend of NPK in coir pith biodegraded using Azotobacter and azospirillum

The principal change brought about in coir pith during composting is the breakdown of lignin which forms the chief constituent. There was a drastic reduction in lignin content from initial 30% to 4.8% in the heap after composting (Table 3 & Figure 11). An important finding from the foregoing studies reveals the fact that composting of coir pith supplemented by combinations of Azolla result in a steep decrease in lignin content (5.2%) from the control value of 30% (Table 4 & Figure 12). This could also be related to the findings of Garcia *et al.* (1980) who reported that white rot fungi are known to have evolved complex enzymatic machinery to degrade lignin, produce extracellullar polyphenols oxidases particularly Lignin peroxidase (LiP), Manganese peroxidase (MnP) and laccases, which are highly effective in depolymerisation of lignin in coir pith. The LiP catalyzes the oxidation of non-phenolic aromatic substrates where as MnP catalyzes the oxidation of Mn^{2+} to Mn^{3+} (Manganous to manganic), which in turn oxidizes many phenolic substrates (Akin *et al*, 1995). Hydrogen peroxide is required for the activity of these enzymes.

Table. 3.Decreasing trend in Lignin content during composting of coir pith (Conventional)

Materials	*Pleurotus sajor caju*					
	Days					
	5	10	15	20	25	30
CP +Urea (0.1%)	30	28.6.	24.2	19.2	14.4	11.1
CP + Urea (0.2%)	30	27.6	24.1	18.9	12.4	10.0
CP + Urea (0.3%)	30	27.5	23.9	18.5	12.2	9.8
CP + Urea (0.4%)	30	27.3	22.8	18.2	11.9	8.8
CP + Urea (0.5%)	30	27.1	20.5	16.3	9.4	4.8
CP + Urea (0.6%)	30	27.1	20.5	16.3	9.4	4.8
Control	30	30	30	30	30	30

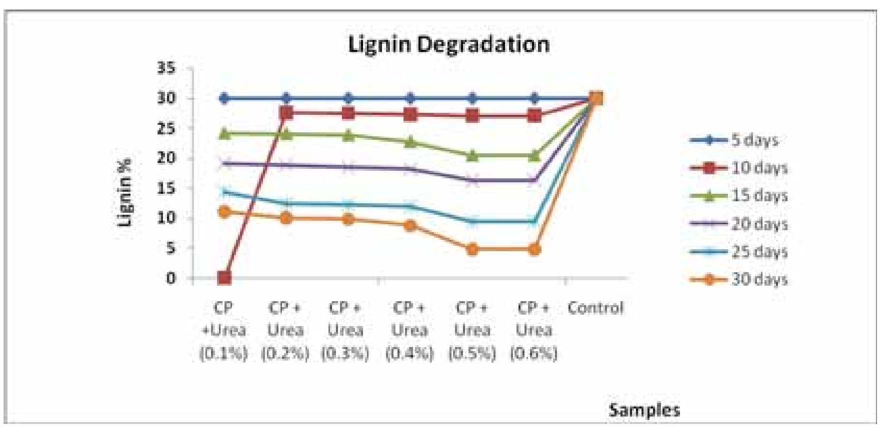


Figure 11. Decreasing of trend of lignin in pith composting (conventional)

Table 4. Decreasing trend in Lignin content during composting of coir pith with azolla as biological supplement

Materials	*Pleurotus sajor caju*					
	Days					
	5	10	15	20	25	30
CP +Azolla (0.2%)	30	28.6.	25.2	21.2	17.4	14.1
CP + Azolla (0.4%)	30	28.6	25.1	21.1	17.4	14.0
CP + Azolla (0.6%)	30	28.4	24.9	20.5	17.2	13.8
CP + Azolla (0.8%)	30	28.2	24.4	20.2	16.1	6.8
CP + Azolla (1%)	30	27.9	23.5	19.3	13.4	5.2
CP + Azolla (1.2%)	30	27.9	23.4	19.2	13.4	5.2
Control	30	30	30	30	30	30

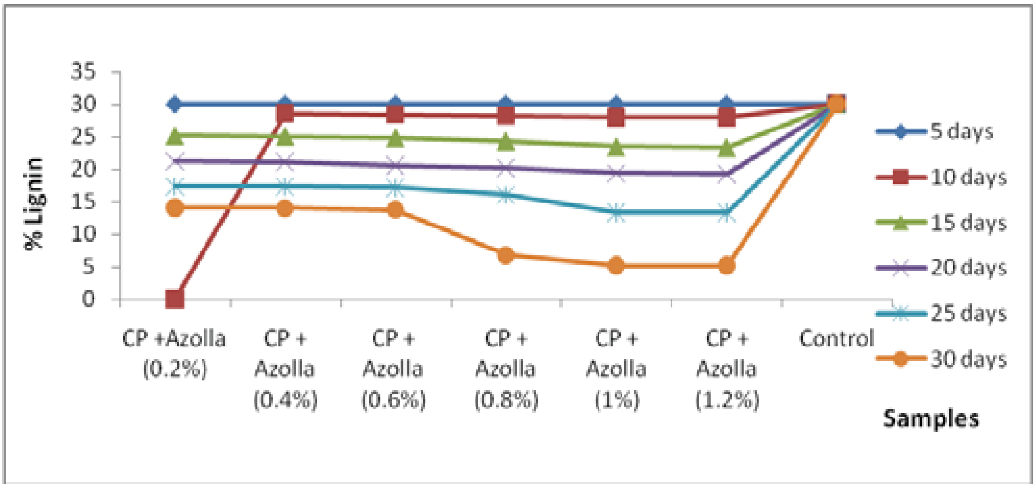


Figure 12. Decreasing of trend of lignin in pith composting (azolla)

The colonization of mushroom cause biochemical changes in pith by utilizing cellulose, hemicellulose and lignin that lead to variations in nutrient status as reported by Wood (1979) and Moorthy (1981). Rajarathinam and Zakia (1998) and De Bertoldi *et al.* (1987) tested the four strains of *Pleurotus* for the degradation of lignocellulose and *P. sajor caju* showed maximum activities of polysaccharide degrading enzymes which could be correlated to weight loss and reduction in lignin content. In the present study it was observed that *Pleurotus sajor caju* showed the lignin degradation capability with the production of requisite enzymes. Thus it is clear that fungal proliferation on coir pith leads to a reduction in organic carbon and lignin content that commenced steadily from the fifth day of inoculation, attained a maximum between fifteenth and twenty fourth day and there after decreased slowly to the minimum. This led to the reduction in lignin content from 32.15% to 5.2% in a period of 25 to 30 days.

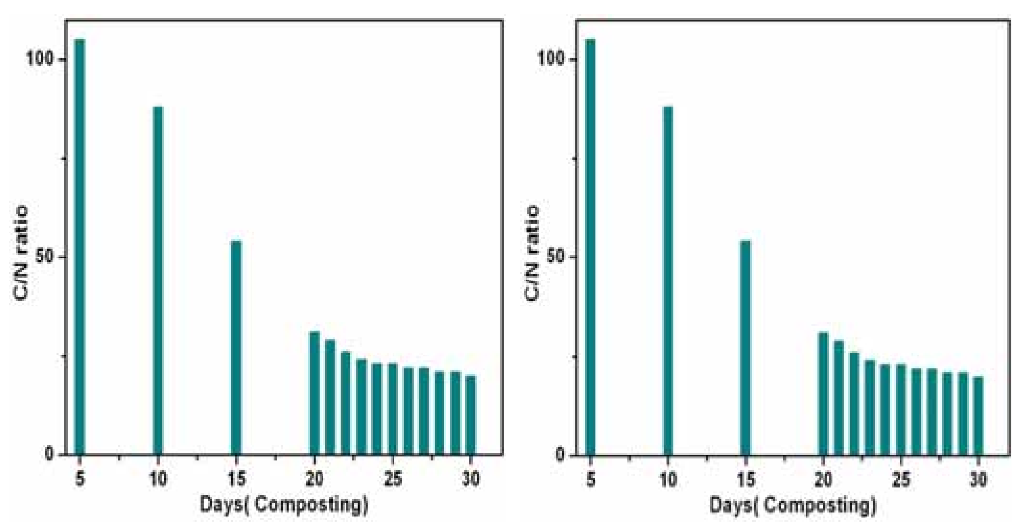
The present study also confirms the earlier findings of Moorthy (1981) who stated that the pH remained high until the end of composting process possibly (30 days) due to progressive utilization of organic substrates and increase in the mineral constituents of waste. The raw coir pith with a pH value of 5.4 shows an increase during composting and raises a neutral value of 6.9 in composted coir pith. Investigation also reveals that incorporation of Azolla, Azotobacter and *Azospirillum* resulted in lowering of EC to 0.21 millimhos /cm in biodegraded coir pith compared to the control value of 1.3 millimhos / cm. The high conductivity indicated in raw coir pith could be attributed to the presence of polyphenols and tannins, which could be reduced by composting with *Pleurotus sajor caju*. Experimental results also showed a decreasing trend in salinity during composting to a tolerable limit of 0-1 ppt from 5 ppt as in raw coir pith by frequent sprinkling of water for maintenance of moisture on composting heaps.

Even though coir pith is enriched with micronutrients and possesses water retention properties which could be exploited for agricultural use, farmers hesitate using it mainly due to wider C: N ratio, presence of tannin related phenolic compounds and high lignin content (Kadalli and Suseela, 2002). Mandhare *et al.* (2003) reported that the C: N ratio of different agro-residues after cultivation of different *Pleurotus* sp shows significant reduction. Bisaria *et al*. (1987) reported that loss in weight of substrate might be due to loss of carbon in the form of carbon dioxide by respiratory activity of

P. sajor caju during its growth. Shetty and Moorthy (1981) reported that the optimum value of C: N ratio for plant growth should be below 30:1. Ghosh *et al.* (2007) suggested that the composted coir pith prepared by the conventional method using urea had exhibited a reduced carbon: nitrogen (C: N ratio) 20:1 from the control value of 112:1 in raw coir pith. The values for carbon and nitrogen obtained from the present study for composting of coir pith with combination of Azolla, *Azotobacter* and *Azospirillum* also result in reduced C: N ratio of 20:1 which is in accordance with the earlier findings of Ghosh.

It has been observed that inoculation of PITHPLUS along with urea as a nitrogen source could result in the vigorous growth of the mushroom accelerating the rate of lignin degradation leading to an increase in the nitrogen, phosphorous and potassium content in coir pith. The composted coir pith obtained after 30 days was observed to have acquired a darker colour than its original form and the particle size was also reduced considerably. It was observed that coir pith is having a particle size of 400 microns was reduced to 10 -50 microns in respect to the volume reduction of from 1 to 0.58 cubic meter during composting. It was also found that the nitrogen content of the degraded coir pith was observed to increase from 0.26-1.26%, phosphorous from 0.01-0.06% and potassium from 0.78-1.20% after 30 days. A significant finding from the foregoing studies reveals that coir pith compost prepared by the addition of urea after 30 days resulted in yielding 1.26% of nitrogen, 0.06% of phosphorous and 1.20% of potassium.

Treatment of mushrooms on coir pith showed variation in pH which was noted to increase to 6.9 from the initial value of 5.4. The variation in pH value indicated changes of acidic nature of coir pith to neutral during composting. Raw coir pith maintained as control indicated a value of 0.98 millimhos/cm for EC, which tends to decrease during composting resulted in lowering the same to 0.21 millimhos / cm. Salinity of raw coir pith was found to range from 3 ppt which tends to decrease during composting (0 ppt). The rate of change of carbon: nitrogen (C: N ratio) in coir pith during the process of degradation was reported by Ghosh *et al*. (2007). Treatment on coir pith with PITHPLUS was observed to display the lowest values for C: N ratio as 19:1 from the control value existed in raw coir pith as 112:1 (Fig 13).



A B

Fig.13. Graphical representation of decreasing of trend of C: N ratio in composting of coir pith (a. conventional b. biological supplements

4. Conclusion

Microbes that are the natural components of soil and water environments are potential agents for the biological degradation of waste which tends to accumulate in the ecosystem. Coir fibre extraction leads to the accumulation of coir pith which causes environmental pollution. Therefore biodegradation of coir pith is essential to control the pollution caused by its accumulation. The conventional process of coir pith composting using urea has been observed to be efficient in lignin degradation but has some disadvantages. The present study leads to the conclusion that Azolla was found to be an alternative and cost effective substitute to urea for ligninolytic degradation of coir pith for solving the problem of environmental pollution. Recommendations for a completely natural organic approach are therefore based on years of collective experience.

5. Diversified uses of Coir Pith and Coir Pith Organic Manure (C-POM)

(a) Growing media

Application of coir pith in soil helps in improving the structure and other physical and chemical properties of the soil. Because of its sponge like structure coir pith helps to retain water and improve aeration in root zone.

(b) As amendment

Coir pith can be used as amendment as it has got higher water holding capacity ranging from 600% to 800% by weight. Incorporation of coir pith will improve the hydraulic conductivity in different layers of soil especially those having sub-soil hard pan. In saline and sodic soils, its application reduced the salt encrustations and improved the soil by conserving moisture

(c) As a substitute to peat moss

Sphagnum is a genus of approximately 120 species of mosses, commonly known as **peat moss**. Accumulations of *Sphagnum* can store water, since both living and dead plants can hold large quantities of water inside their cells; plants may hold 16–26 times as much water as their dry weight, depending on the species. The empty cells help retain water in drier conditions. Hence, as sphagnum moss grows, it can slowly spread into drier conditions, forming larger mires, both raised bogs and blanket bogs. These peat accumulations then provide habitat for a wide array of peat land plants, including sedges and ericaceous shrubs, as well as orchids and carnivorous plants. Exploitation of peat moss for horticultural purposes in New Zealand, Ireland and the Baltic countries has been facing stiff opposition from the environmentalists, as it has resulted in destruction of wetland in these countries. Coir pith provides the soil less medium for growth of nursery plants and has been used extensively in various countries for the purpose. There are vast unexploited opportunities for export of Coir pith because of emerging market opportunities for this product in the developed and growing economies of the world.

(d) As an organic fertilizer

The concept of food for all in Green Revolution resulted in degradation of natural soil fertility due to the continuous use of chemical fertilizers. Chemical fertilizers were used as a temporary measure, as a part of soil nutrient management and it does not take care of the soil organic matter. Maintenance of soil organic matter, therefore assumes greater importance especially in tropics and subtropics. The main constraint in maintaining level of organic matter in soil is non-availability of the requisite quantity of organic manures. Composting is the biological conversion of waste material, under controlled conditions, into a hygienic, humus rich, and relatively bio-stable product that conditions soil and nourishes plants. A process of composting has been standardized by Central Coir Research Institute (Coir Board) for preparation of organic manure / fertilizer out of coir pith using urea as nitrogen supplement thus obtained is rich in nitrogen (1.26%), phosphorous (0.06%) and potassium (1.20%) which is essential for plant growth.

(e) As a base for Home /Vertical/Roof garden

Roof gardens have gained attention in recent years as an urban horticulture alternative with advantages. The plant material destroyed during the construction phase can be restored at the top of the building and may reduce the adverse effect of urbanization. It has also been known that there is 50% reduction in the heat flux into building due to solar irradiance be roof gardening. This offers increase in the lifespan of the buildings from UV, high temperature and rapid fluctuation of temperature damages. Vertical gardening is an innovative, effortless, and highly productive growing system that uses bottom-up and top-down supports for a wide variety of plants in both small and large garden spaces. The vertical gardening has advantages over other types viz. less space, increased beauty etc. Vertical gardens are ideal for people with arthritis and mobility issues. Terrace garden also a gardening practice which were getting tremendous attentions in urban areas like flats and multi floored villas**.** Coir Pith Organic Manure (C-POM) developed by the Board using PITHPLUS, a mushroom spawn is an efficient cultivating media for Ornamental, Medicinal and Vegetable plants.

(f) As a base for the preparation of Cocolawn

COCOLAWN is a lush green readymade lawn of grass using various materials of coconut husk viz coir geotextiles, coir needled felt /coir fibre, coir pith and Coir Pith Organic Manure (C-POM) developed by Central Coir Research Institute, Coir Board. It is a natural, eco-friendly lawn and a better substitute of synthetic lawn presently made. The lawn is encased in a composite comprising a single or multiple layers of non woven coir fabric embedded in coir netting .Grasses of choice can be grown to prepare the lawn. The ready-to-use lawn can be rolled like a blanket. The lawn is encased in a composite comprising a single layer of coir fibre embedded in coir netting or coir geotextiles. A layer of coir pith is placed on the fibre. Grass slips are planted on the coir pith bed so made and Coir Pith Organic Manure (C-POM) is sprinkled thereon to form a thin layer. Grass of choice can be grown to prepare the lawn (Figure 11). It is easy to shift the material from one place to another and it can be rolled for transportation. The open weave structure of supporting fabric ensures complete drainage of excess water and helps in supporting roots of the planted grass saplings and protects bare surface otherwise vulnerable to erosion by rain and wind while grass develops to provide long-term protection.

1 MT Coir Pith + 2 kg Pith plus + 5 kg Urea = C-POM

Figure 11. Coir based lawn (4 distinct layers)

8. Acknowledgement

The authors would like to express his gratitude to Shri.C.P.Radhakrishnan, Chairman, Coir Board for his keen interest and encouragement.

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BINDERLESS COIR WOOD

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Abstract

The coconut husk is abundantly available as a byproduct of coconut production in many areas, which is known to yield the coarse coir fibre. Using the intrinsic resin properties of lignin, high quality particle boards can be made by the compression moulding process without the addition of any chemicals and binders. Binderless boards were produced from coir pith, bit fibres and also from used coir mattings without any mechanical pretreatment. The processing conditions such as time, temperature and pressure could be optimized to get good quality binderless boards. The mat touch wood finished boards exhibit water absorption properties, which are comparable to commercial plywood based panels. The boards can be handled with common wood working equipment for drilling and sawing making them suitable for indoor paneling in building.

Introduction

Coconut husk is abundantly available in all tropical countries as a cheap residue of coconut production, from which the coir fibre for the production of woven carpets, ropes, brushes and matting are extracted. This can be achieved by retting or mechanical decortication. The coconut husk comprises 30% by weight coir fibres and 70% pith. Both fibre and pith are extremely high in lignin and phenolic content. The lignin present in the coir fibre and pith act as a thermosetting binder resin. Using the intrinsic resin properties of lignin, high quality particle boards can be made by the compression moulding process without the addition of chemicals and binders. The largely unutilized biomass resource can be transferred into a valuable feedstock for the production of wood substitute products. The lignin is typically for monocotyledonous plants rich in syringyl with appreciable amounts of p-hydroxyphenyl units. The coir fibre is composed of at least one third of Klason lignin while lower molecular weight phenolics can be found as extractives in considerable amounts, especially in younger nuts The thermal behavior of the original (chemically unmodified) lignin in the plant tissues at temperatures above 140 °C, where it melts and shows thermosetting properties needs to be explored for application as intrinsic resin in board production [1]. Based on this concept, a simple and efficient technology has been developed to produce high strength–high density panels, without addition of chemical binders. The eco-friendly production of binderless boards from coir pith as wood substitute could create novel economic activities in rural areas. The binderless board produced from coir is 100% ecofriendly as there are no harmful emissions, no chemical treatment required for the production and there are no byproducts during the production process of the boards. The boards so produced can be utilized for the application as acoustic absorbing panels, since coir fibre and pith contains large number of voids in it.

Production of binderless boards from the whole coconut husk has been reported by other workers [2] with a mechanical pretreatment. In the present study coir bit fibres, used coir mattings and coir pith each were used separately for the production of binderless boards without any mechanical pretreatment. The use of coir bit fibres and used matting leads to the utilization of waste material that may otherwise be burnt or accumulate causing disposal problems.

Materials and methods

Materials

Coir pith, used coir matting and coir bit fibres were collected from Alleppey, Kerala.

Methods

Drying of the materials

The raw materials needs to be dried before hot pressing so as to remove the moisture present in the materials. The presence of moisture in the material creates air entrapments in the board and may lead to deterioration in the strength of the boards. The materials are dried in a standard hot air oven maintained at a temperature of 100˚C for 1-2 hours depending upon the moisture present in the material. The moisture content is measured in Moisture analyser LJ16, Metler Toledo, Japan and ensures to be below 10%.

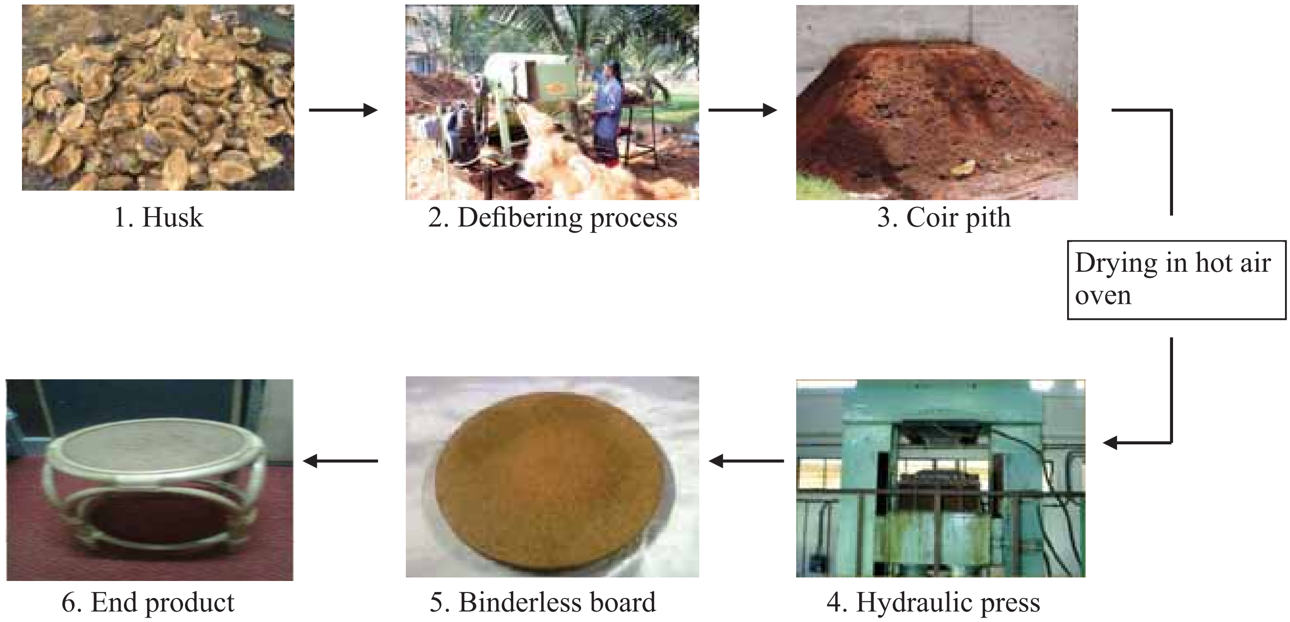
Sieving

The coir bit fibres and coir pith material is sieved in a standard IS 100 mesh sieve to remove the foreign materials present and to ensure a uniform particle size distribution. The boards produced from particles of less than 5mm size shown higher strength compared to the board produced from bigger size particles.

Hot pressing

The coir bit fibres and pith were compressed in a hydraulic press at elevated temperature and pressure at compression ratio of 1:15 ie. the material fills in the mould at a height of 15cm and compressed to a thickness of 1cm. In the case of matting boards the compression ratio is comparatively less and 2-4 pieces of the matting cut in to the required size and placed in the mould and compressed. The boards are compressed for the required time 20-30min depending up on the thickness of the product. The boards are allowed to cool under pressure for another 30min and ejected from the mould.

The flow chart below explains the different stages in the production of binderless boards from coir pith



Determination of water absorption

In the present study, the samples were immersed in water for the desired time intervals. The water absorption was measured by the difference in weight of the samples after immersion in water.

The % of water absorption was calculated by the following equation:

$$\% \text{ water absorption} = (W_2\text{-}W_1 / W_1) \text{ X } 100$$

Where W_1 is the weight of the sample before immersion in water and W_2 is the weight of the sample after immersion in water [3].

Results and discussions

Effect of Moisture

Coir fibre and pith are hygroscopic in nature. About one third of the fibre is filled by air to give it the property of resilience. Coir pith has a porous structure and having high water holding capacity of 625-800% [4]. The presence of moisture in the material creates air entrapments in the produced boards and may lead to deterioration in the strength of the boards. Trials were conducted with raw material having different moisture contents and found that that the material having a moisture content of less than 10% produces boards with excellent finish and strength. The raw material should be dried to a moisture level of less than 10% before hot pressing.

Effect of Temperature

The thermal behaviour of the original (chemically unmodified) lignin in the plant tissues shows thermosetting properties as it melts at temperatures above 140 °C. Trials were conducted at different temperatures from 140°C to 180°C and found that 150°C is ideal for binderless board production. At lower temperatures proper setting of the board has not taken place and at higher temperatures charring of the board observed. At 150°C sufficient flow and setting of the lignin is observed in the produced boards.

Effect of pressure and cooling under pressure

Trials were conducted at different temperatures and optimized the pressure at 200kgf/cm2 in the hydraulic press. At low pressures, the flow of lignin doesn't take place and the produced boards shown moisture absorption and loss in strength on exposure to the atmosphere.

Another important parameter to be taken care in the production of binderless coir boards is cooling under pressure. The produced boards were allowed to cool under the applied pressure for half an hour. After the required cooling period, boards are ejected from the mould. Bending of the boards observed if it is not cooled under the applied pressure inside the mould.

Machining

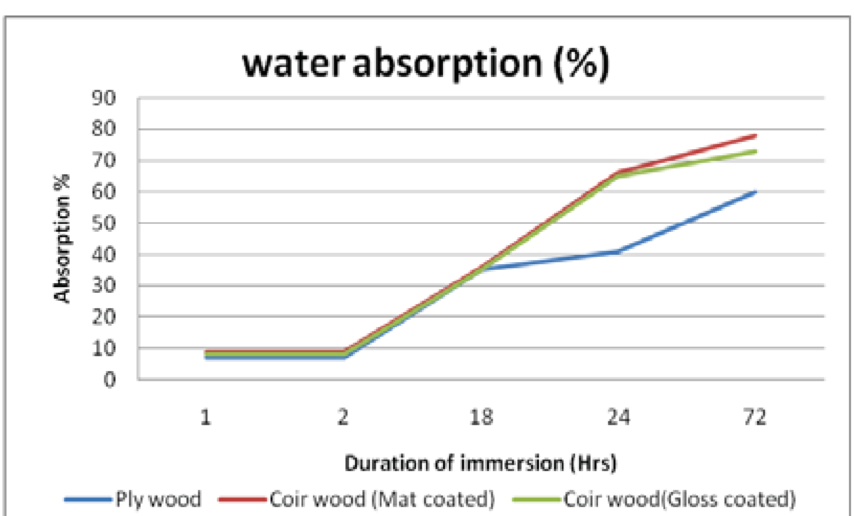
The binderless boards produced from coir fibre and pith was subjected to conventional machining operations such as sawing, cutting using high speed cutter and drilling operations. The results have been observed to be comparable with the conventional ply wood and MDF.

Water absorption studies

The boards having a thickness of 10mm were cut in to pieces and coated with mat and gloss touch wood finish and the water absorption characteristics were studied by immersing in water and compared with ply wood having the same thickness. The results were as follows.

Table 1. Water absorption study

Duration of immersion in water	% of absorption		
	Ply wood (10mm Thickness)	Coir pith board (Mat coated)	Coir pith board (Gloss coated)
1hr	7	9	8
2hrs.	7	9	8
18 hrs.	35	36	35
24Hrs.	41	66	65
72Hrs	60	78	73



Conclusion and future line of work

The optimized temperature and pressure for the production of binderless boards is 150˚C and 200kgf/cm2 respectively. The pressing time varies depending upon thickness of the product. Good quality binder less boards can be developed from the coir pith, fibre and matting using the intrinsic resin properties of lignin. The binderless boards so produced can withstand high speed cutting and drilling operations. The initial water absorption of coated boards with mat and gloss touchwood found to be comparable with plywood after immersion in water.

The production of binderless boards from coir need to be standardized by evaluating its strength and acoustic absorption characteristics that can be used for structural applications as acoustic absorption panels and impact resisting applications.

Acknowledgement

The authors are very much grateful to Coir Board, Cochin and Central Coir Research Institute (CCRI), Kalavoor for permitting to conduct the studies.

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Promotion of Rubberized Coir as Seat Cushions in Railways.

S. SUNDARESAN, PRESIDENT, ALL INDIA COIR MATTRESS MANUFACTURERS' ASSOCIATION, BANGALORE

Rubberized Coir is an excellent Seat Cushioning material & entirely made from local raw material – Coir, Fibre & Natural Rubber Latex. Thus this product is eco-friendly & totally aligning to our Honorable Prime Minister's vision of **"Make in India".**

Some of our member manufacturers have a high level of technical competency & also the necessary resources coupled with R & D facilities to meet the required specifications of Railways.

We are interested in working with the Railways on this matter. It will be very helpful if we have the necessary backing, support & push of both the Coir Board & MSME Ministry.

It is our request that you use your good offices & giving us a chance to prove our credentials.

We can start in small manner by sponsoring the entire seat cushions in couple of coaches in whichever train the Railway Ministry may choose.

<u>Reduction in Import Duty of Latex Rubber:-</u>

Request for reduction of basic customs duty (BCD) on import of natural latex rubber [classifiable under HSN Code 4001 1020] meant for use in manufacture of rubberized coir mattresses and sheets from 70% to 25% to make it at par with import of natural rubber in dry form [classifiable under HSN code 40012100] used by Tire manufacturing industry

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General Overview

1. The Government of India (Ministry of Finance) provides various fiscal incentives to the manufacturers and exporters of various coir products. The manufacture and sale of coir products namely Coir Mattresses/sheets entails an incentivized rate of excise of2% or 6% and the export of such products includes benefits under the duty drawback scheme and MEIS scheme under the FTP. Further, many State Governments recognized rubberized coir as "wealth from waste" and advocated the use of rubberized coir mattresses in various hospitals, health clinics etc. through issue of Government circulars.

2. The sector centrally falls in line with the Prime Ministers 'Make in India' scheme with majority of the inputs procured from un-organized sectors (workers engaged in this activity mostly based out of the rural parts of the country) and the products fully manufactured in India are sold locally or exported out of India.

3. The Coir mattresses/sheets are manufactured by coir husk, rubber, latex and adhesives. This

sector generates self-employment to the various coir husk, rubber and latex suppliers who majorly operate in the un-organized sector based in and around rural areas.

4. Further, the Industry and Coir Board have together worked towards better utilization of coconut husk by consuming brown fiber thus extracted. There are about five lakh workers mostly in the rural side which are engaged in this activity. It is further estimated that only about 60% of the husk is utilized for extraction of fiber and balance being burnt as fuel. Thus there is tremendous scope in further extracting the fiber from the husk.

5. The Coir Industry was at its peak around the year 2010 wherein the total estimated production was around one lakh ton per annum. However, this capacity has drastically reduced in the financial year 2014-15 wherein the Rubberized Coir production was less than 60,000 tons. This drop of 40% is in spite of the fact that in this period the mattress industry may have grown by 40% is on account of other competing products like Polyurethane Foam, Spring various other Synthetic polymers and Synthetic fibers entering the mattress industry. The one of the possible reason for such decline is also the levy of excise duty @2%/6% effective from March 1, 2011 on the coir mattresses including Rubberized Coir Mattresses and Sheets which has resulted in increase of the cost of production and prices.

Overview of Coir products including mattresses industry

6. In this context, it is submitted that Rubberized Coir is an organic product as the important raw materials going into their manufacture are vegetable derivatives – viz – from rubber and coconut trees and a lion's share is coconut fiber. As such, this product is bio-degradable and so is eco-friendly. This is the first consideration in its favor, especially when compared to its competitors, both PVC and U Foam and synthetic products. In the present day when environment and ecological considerations are top-most in every discerning person's mind, it is only natural that all encouragements and incentives are to be given to increase its production and propagating its use everywhere.

7. It is a native product making use of indigenously available/produced materials and so no royalty of any kind is payable to any foreign companies. It is a product of India, by Indians and for Indians. The Rubberized coir industry is thus helping the poorest of the poor villagers in generating employment in coconut farming, plucking, de husking, de fibering, coir making and as an industry it gains added importance as most of the units are set up in rural and semi-urban areas. To encourage this industry to enable it to offer better benefits to end users, the Government may think of extending benefits similar to those given to Khadi & Village products and hand loom as the ultimate beneficiaries of this industry are the poor and downtrodden.

8. Further, the promotion of coir based mattresses would also promote healthy environment as Coir is made from natural fiber hence it is environment friendly and no chemicals are used in its manufacture hence it is good for health and environment. Further, Coir is well known for its health benefits and in particular, coir mattresses give a healthy and rejuvenating sleep as they provide a firm support, which is medically recommended for a sound sleep.

Basic Customs Duty on import of natural latex rubber [classifiable under HSN Code 4001 1020] used in manufacture of rubberized coir mattresses and sheets vis-à-vis natural rubber in dry form [classifiable under HSN code 40012100]

9. We have tabulated below the present duty structure on both types of natural rubber:

Type of Rubber	HSN Codes	Current Basic Customs Duty Rate	Usages
Natural rubber in other forms [dry rubber]	4001 2100	25%	Tire manufacturing industry
Natural latex rubber	4001 1020	70%	Rubberized Coir mattress and sheets manufacturers

10. As can be observed from the above comparative statement, the basic customs duty (BCD) on natural latex rubber is almost thrice of the duty payable on imports of natural rubber in other form (dry form).

11. The BCD on Natural Rubber in other form (dry form) was reduced earlier to enable the tire manufacturers to reduce their manufacturing costs and in turn reduce the prices of tires so as to support transportation sector in the country.

12. It is submitted that the above unintended anomaly resulting in huge difference in rate of BCD can be seen as providing incentives and benefits to one industrial sector namely tire manufacturing/ transportation sector whereas it discourages the another labor incentive manufacturing sector namely rubberized coir products and sheets. Such anomaly is required to be addressed at the earliest to 'make in India' a huge success.

Request–To reduce the BCD rate on natural latex rubber to 25% to make it at par with the duty rate on other natural rubber products

13. We as an industry are overly concerned with the declining production coupled with increased competition and availability of cheaper alternatives including emergence of PU foam based mattresses and related products. Given the scenario, the sector has remained almost stagnant and has not seen any major investment in the past 5 years causing a turmoil in the continuity and growth of the indigenized sector.

14. It is submitted that that the promotion of coir based products would also help the small scale sector and clean products and also generates employment as well as disposable incomes in the hands of people living in villages/under-developed part of India. Concession to this industry will make it preferable in the furnishing of railway passenger coaches, bus seats, cinema theatre seats and cushioning materials for hotel resorts, thus enlarging its domestic market.

15. **In light of above, it is requested either to reduce the rate of BCD from 70% to 25% in general on import of natural latex rubber classifiable under HSN Code 4001 1020 or reduce the rate for the mattress industry for use in manufacture of rubberized coir mattresses or sheets**.

Rubberized Coir Under GST:-

Request for classifying the Rubberized Coir products under the merit/essential goods list i.e. lower tax bracket under proposed GST regime

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Overview

1. The Government of India (Ministry of Finance) provides various fiscal incentives to the manufacturers and exporters of various coir products. The manufacture and sale of coir products namely Coir Mattresses/sheets entails an incentivized rate of excise of2% or 6% and the export of such products includes benefits under the duty drawback scheme and MEIS scheme under the FTP. Further, many State Governments recognized rubberized coir as "wealth from waste" and advocated the use of rubberized coir mattresses in various hospitals, health clinics etc. through issue of Government circulars.

2. The sector centrally falls in line with the Prime Ministers 'Make in India' scheme with majority of the inputs procured from UN-organized sectors (workers engaged in this activity mostly based out of the rural parts of the country) and the products fully manufactured in India are sold locally or exported out of India.

3. The Coir mattresses/sheets are manufactured by coir husk, rubber, latex and adhesives. This sector generates self-employment to the various coir husk, rubber and latex suppliers who majorly operate in the UN-organized sector based in and around rural areas.

4. Further, the Industry and Coir Board have together worked towards better utilization of coconut husk by consuming brown fiber extracted. There are about five lakh workers mostly in the rural side which are engaged in this activity. It is estimated that only about 60% of the husk is utilized for extraction of fiber and balance is burnt as fuel. Thus there is tremendous scope in further extracting the fiber from the husk.

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6. We as an industry are overly concerned with the declining production coupled with increased competition and availability of cheaper alternatives. Given the scenario, the sector has remained almost stagnant and has not seen any major investment in the past 5 years causing a turmoil in the continuity and growth of the indigenized sector.

Indirect Tax scenarios

7. As mentioned above, currently the coir mattresses and sheets are subjected to lower excise duty of 2% (without Cenvat) and 6% (with Cenvat). Further, the VAT rates varies from 5% to 15.5% on the various coir products. Accordingly, it can be clearly observed that the effective rate on the **Rubberized Coir** products are around 18% and well below the higher tax rate of around 28% [Excise rate of 12.5% and VAT rate of 15.5%].

8. We understand basis the information available in the public domain that the exemptions and tax incentives currently available to various sectors under Central and State indirect tax regimes, would be withdrawn and would no longer be available under the proposed GST regime.

9. We as an industry are overly concerned with the declining production coupled with increased competition and availability of cheaper alternatives including emergence of PU foam based mattresses and related products. Given the scenario, the sector has remained almost stagnant and has not seen any major investment in the past 5 years causing a turmoil in the continuity and growth of the indigenized sector.

10. It is submitted that that the promotion of coir based products would also help the small scale sector and clean products and also generates employment as well as disposable incomes in the hands of people living in villages/under-developed part of India. Concession to this industry will make it preferable in the furnishing of railway passenger coaches, bus seats, cinema theatre seats and cushioning materials for hotel resorts, thus enlarging its domestic market.

11. In light of the above, it is requested that the coir products including coir and rubberized coir mattresses and sheets be classified under the merit/essential list i.e. under the lower tax bracket under the proposed GST regime so as to continue incentivize and promote the Industry.

P.K.RAVI*

Rubberised coir

Any coir product which contains rubber whether synthetic, natural or reclaim may be termed as rubberised coir. Rubber latex and rubber sheets are used in coir industry for making rubberised coir products.

Classification:

They are broadly classified into the following 5 groups

1. Rubberised coir mattress & Cushions
2. Latex backed coir mats / matting
3. Rubberised coir fiber for the manufacture of various garden articles
4. Rubber backed coir mats
5. NR Latex tufted mats

History of Rubberised Coir Industry

Soon after 1st world war, the rubberised coir industry originated in Austria. In the following years, it spread to other parts of Europe and the world. Rubberized coir, produced from curled coir and natural rubber latex was the backbone for the rubberized coir industry all over Europe.

During 2nd World War when Germans wanted armaments and tanks to be air shipped in different battlefields, they needed cushioning material, which would withstand the impact so that the equipment and tanks dropped from planes would not be damaged. Rubberised coir cushioning material being an inexpensive material could be discarded after use and was considered most suitable. The coir fibre was used as replacement of horse hair for cushion filling material for the Volks Wagon Car of Germany prior to 1960.

Though India is one of the largest coconut growing and rubber producing countries in the world, the rubberised coir industry made its beginning in India only in 1961 itself with the licence granted by the Government of India to Bharat Motors, to set up a rubberisation plant at Tirunelveli of Madras state in 1961.and large scale production of rubberised coir was started only in 1964.Transportation of rubberized coir is not economical as it needed to pay freight for 10-ton capacity trucks for carrying only 21/2 tons of mattresses because of its voluminous nature.

Natural Rubber Latex – Its Source, Composition and Properties

Natural rubber (NR) latex is obtained directly from the Hevea brasiliensis rubber tree, by tapping and collecting the latex in small cups which flows from the spiral cut made almost through the bark,

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but just short of the cambium or growing layer. The latex is a stable dispersion of rubber in water, proteinous material being the dispersing agent.

Composition of NR latex

Sl.No.	Content of Ingredients	Per cent,%
1	Rubber hydrocarbon	35.0
2	Non-rubber solids(Proteins, lipids, sugars, resins, fatty acids, alkaloids, inorganic salts etc.)	5.0
3	Water	60.0

Rubberised coir is a high quality packaging and upholstery made from curled coir bonded together by rubber latex. When NR latex is employed as the binder, improved load bearing capacity and excellent resistance to compression set are imparted to fibrous structures. Such properties ensure that after compression of any extent or duration whether due to shock or static loading, the structure rapidly recovers to its original shape, a pre-requisite of any good upholstery or packaging material.

The natural latex collected from the tree, called field or normal latex contains, 30 to 40% rubber hydrocarbon. The normal latex contains all the serum substances, finds limited uses because of its dark colour, strong odour and other objectionable features.Naturally occurring proteins and phospholipids stabilize latex fresh from the tree. The protein stabilizer is very susceptible to bacterial action and would be destroyed within a few hours if ammonia were not immediately added. The rubber latex collected from the tree is a highly perishable material, which will putrefy and coagulate in a few hours unless a preservative is added.

In all latex applications stirring or pumping and addition of compounding materials, are involved. Thus mechanical and chemical stability are essential.If latex is preserved entirely by high ammonia (HA), a portion of the ammonia is removed before application. The low ammonia latex has advantages of lower cost and elimination of the need to de ammoniate the latex before processing into products.

Main function of the latex

It acts as a binder to reduce deformation of the structure during service. It increases the load bearing characteristics.

Raw Materials for rubberized coir mattress

Natural rubber latex and Curled coir rope

Natural Rubber Latex Concentrates

Natural rubber latex is concentrated to increase the rubber content and to improve the economics of shipping. There are three principal concentration methods: centrifuging, evaporating and creaming

Centrifuged Latex

Centrifuging is the most favoured method and accounts for 90 % of all concentrate. Blended field latex is ammoniated and centrifuged to give 60% rubber concentrate. Centrifuged latex is suitable for all normal latex processes.

Evaporated Latex

In the evaporated process the field latex is normally stabilized with soap and an alkali in preference to ammonia. Water is removed from the latex in film evaporators. The resulting latex possess high solids content (72% or more)

Creamed Latex

In the creaming process the field latex is treated with a fatty acid soap and a creaming agent, filtered warmed to 40^0 C and then stored in bulk creaming tanks. After a few weeks the rubber rich cream layer has separated from the serum and the cream can be separated and homogenized to give a concentrate of 66-68 % rubber content

Preservatives

A preservative is essential to inhibit bacterial growth which would destabilize the latex and ultimately bring about spontaneous coagulation. Centrifuged and creamed lattices are normally preserved with ammonia which has the advantage of being completely volatile, leaving no residue in the product. A secondary preservative may be used with a reduced ammonia content.

Commercial types of NR latex concentrate

Centrifuged types

There are four types of centrifuged latex concentrate, differing in their preservative systems.

1. High ammonia latex (HA), preserved with not less than 0.61% ammonia by latex weight
2. Low ammonia latex (LA-SPP), preserved with not more than 0.31% of ammonia by latex weight and 0.2 % by latex weight of sodium pentachlorophenate.
3. Low ammonia boric acid latex (LA-BA), preserved with not more than 0.31% ammonia by latex weight ,0 .2 % by latex weight of boric acid and 0 .04 % by latex weight of lauric acid.
4. Low ammonia zinc diethyldithio carbamate latex (LA-ZDC) , preserved with not more than 0.31% ammonia by latex weight, 0.1% by latex weight of zinc diethyl dithiocarbamate and 0.02% by latex weight of lauric acid.

Requirements for Centrifuged and Creamed Natural Rubber Latex Concentrates

Sl No	Characteristics	Requirements for centrifuged NR latex			Requirements for creamed NR latex	
		Type HA	Type MA	Type LA	Type HA	Type LA
1	Total solids content, % by wt(min)	61.5	61.5	61.5	66.0	66.0
2	Dry rubber content, % by wt(min)	60.0	60.0	60.0	64.0	64.0
3	Non rubber solids,% maximum	2.0	2.0	2.0	2.0	2.0
4	Coagulation content, % by wt of total solids,(max)	0.08	0.08	0.08	0.08	0.08
5	Sludge content, % by wt(max)	0.10	0.10	0.10	0.10	0.10
6	Alkalinity as ammonia % of water content	1.6 min	Above 0 .8 but below 1.6	0.8 max	1.6 min	1.0 max
7	KOH number, max	1.0	1.0	1.0	1.0	1.0
8	Mechanical Stability seconds, min	475	475	475	540	540
9	VFA Number, max	0.15	0.15	0.15	0.15	0.15
10	Copper content ppm of total solids, max	8.0	8.0	8.0	8.0	8.0
11	Iron Content, ppm max	5.0	5.0	5.0	5.0	5.0
12	Manganese, ppm max	8.0	8.0	8.0	8.0	8.0

Curled Coir Rope

A product made out of mechanically extracted coir fibre by regulated and even feeding of the fibres with the help of a mechanical arrangement in curling machines to form a thick strand of evenly distributed parallelised fibres which is processed further to form twisted curled rope of continuous length. The texture of machine twisted curled fibre shall be hard twisted with curls evenly distributed along the length.

Quality parameters of Curled coir rope (IS 9308 (Part 4) – 1999: Specification for Mechanically Extracted Coir Fibres- Machine Twisted Curled Coir Fibres.)

Sl.No.	Parameter	Requirements
1	Twist	16 to 24 curls per 300 mm
2	Diameter	15 to 19 mm variation in diameter should not exceed 3 mm
3	Mass of coil	25 to 30 kg
4	Long fibre % (Min) (above 200 mm)	10.0
5	Medium fibre % (Max) (above 150 mm and up to 200 mm)	50.0
6	Short fibre % (max) (above 50 mm and up to 150 mm)	20.0
7	Moisture content % (Max)	15.0
8	Impurities % (Max) (pith dust, bits of exocarp and fibres below 50mm)	10.0
9	Chloride content % (Max)	0.60
10	Sulphate content % (Max)	0.25
11	Texture	Hard twisted with curls evenly distributed along the length
12	Twist, Diameter and mass of coil as agreed to between the buyer and the seller.	

Process of Manufacture of Rubberised Coir

There are two methods of manufacturing rubberised coir. In the 1st method, products of simple shape are made by applying latex to a pre formed pad of fibres, usually with a spray gun. The pad is then dried in hot air and the product is cut from the resulting pad and vulcanized in a mould. In the 2nd method, the fibre is first treated with the latex and then shaped in perforated metal or wire moulds before drying and vulcanization. The first method is usually used for sheet manufacture, while the second is preferred for articles of irregular shape.

Choice of fibre for Rubberised coir mattresses/cushions

In both the methods, the choice and preparation of fibre is important to achieve the best results.

Retted coir used for spinning of yarn is not suitable for rubberisation. This is because soft fibre will not retain the curling done by machines and consequently rubberised coir mattress will sag soon. The fibre needs to be fully matured and hard so that a spring like consistency given to it during twisting process retains sufficiently long to satisfy the requirements. The fibre should be free from salt. Any salt content in the fibre will adversely affect the rubber solution spread on it; make it difficult to vulcanize the product. The resiliency is due to the springing quality of the fibre and it is desirable to use about 70 % of fibre for producing the best quality of rubberised coir products.

Curling

It is essential that the coir fibre should be thoroughly curled. Curling the fibres like a spring improves the resilience of the product. The various types of fibre are picked up by conveyor belts, which are synchronized to deliver a pre-determined blend of fibres. After blending, spinning machines automatically orient the loose fibres and form them in to tightly twisted rope, which brings about the curling effect. The twisted ropes may then be steamed to accentuate the curl and make it more permanent. The fibre ropes are then cut in to bales and stored as long as possible to "set" the curl so as to get improved curling effect before being opened for use.

Pre arrangement of fibres

At the commencement of the rubberisation process, the bales of curled coir are efficiently opened and finally divided to give what amounts to a very large number of minute coir springs which retain the curl and it imparts the resiliency to the body of the product. The structure of the fibres has a considerable effect on load bearing properties and therefore weight and cost of the finished product. After opening, the curled coir fibres are arranged in a loose consistency either by carding, web-formation or some such suitable means or hand to form a uniform structure (pad formation) in such a way that the whole mass can be sprayed throughout with ease. To facilitate this, the mass should be so arranged that its height does not exceed 2". Complete automatic machinery is used to obtain even distribution and orientation of fibre,an essential characteristics of rubberised coir manufacture.

Spraying

The fibre structure is then treated with latex binder. The main function of the binder is to reduce deformation of the structure during service but it also increases the load bearing characteristics. The latex is usually introduced with the aid of automatic spray guns but it is difficult to achieve adequate penetration of the structure in one operation. The compounded latex is sprayed on the fibres by an oscillating mechanism. The spray gun provide for fine adjustment of the spray and enable the desired amount of latex to be deposited on the articles being sprayed. Spraying latex also provides an easy means of rubberising fibrous materials when a moderate degree of penetration is satisfactory such as rubberised fibre in a continuous process.

Complete impregnation is accomplished by separate spraying operations from opposite sides. To achieve this, one side of the pad is sprayed first, after which the pad is dried by passing through a heated chamber. The pad is then turned over by passing over a bar, which is oriented at 45^{o} to the direction of the pad, which is travelling for second spray application. This has the effect not only of turning the pad over but also of turning its direction of movement through one right angle.

Drying

After spraying the other side, the fleeces are dried at 70-80^{o}C in hot air. The drying chambers are provided with hot air blower and exhaust; all movements are synchronized for continuous delivery of rubberised fibre. The time should be sufficient for drying the mass without any apparent vulcanisation.

Fabrication and Vulcanisation

Thick pads can be built up from partially vulcanised thinner fleeces by coating their surfaces with latex compound and vulcanising the composite block under slight pressure in a mould. Irregularly shaped articles like automobiles seats are made from blocks of rubberised coir bonded together with rubber latex.

The drying and vulcanising conditions required would depend on the density and thickness of the pad being made and on the oven air velocity, which serves as the heat transfer medium. A high velocity air can reduce drying and vulcanising times dramatically. Care should be taken to avoid over curing.

The fibre block is covered on top with polyurethane foam or latex foam as per the customer's requirements.

Quality of rubberised coir mattress

The quality of rubberised coir products depend on quality of curled coir, rubber to coir content ratio (40:60) and processing techniques.

Characteristics of Rubberised Coir cushion

Low density

Open network of fibres

Light weight

Hygienic

Washable

Non allergic

Cool & Comfortable

Resilient and porous

Durable and Cushioning material

Moth and mite free

Versatile product

Can be moulded to any shape and contour

Applications of Rubberised Coir

Mattresses and cushions for homes and hospitals

Industrial Packaging

Air filters & Ventilating screens in industries

Thermal and acoustic, insulation pads

Carpet underlays.

Industrial cushioning-Bus seats, automobile cushioning.

Quality parameters for Rubberised Coir Mattress

1. Indentation hardness index
2. Resistance to flexing
3. Resisting to ageing
4. Compression set: aged & unaged
5. pH value
6. Chloride content
7. Sulphate content
8. Density

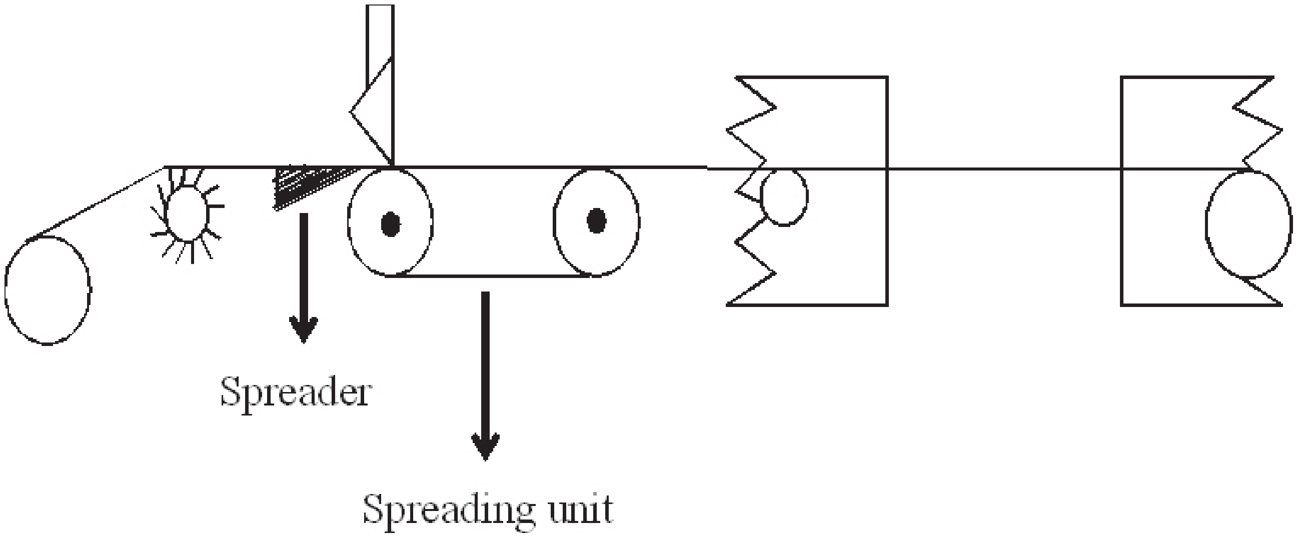
Latex foam backed coir matting

IS 8931-1987 :Specification for Rubberised Coir Sheets for Cushioning

Parameter	**Grade 1 Soft**	**Grade 11 Medium**	**Grade 111 Firm**	**grade iv Extra firm**
Indentation Hardness, kg	3 to 5.99	6 to 8.99	9 to 11.99	12 to 15
Resistance to ageing %	$\pm$20 %	$\pm$20 %	$\pm$ 20 %	$\pm$20 %
Resistance to flexing %	$\pm$20 %	$\pm$20 %	$\pm$20 %	$\pm$20 %
Compression Set, Aged %	$\pm$20 %	$\pm$20 %	$\pm$20 %	$\pm$20 %
Compression Set, Unaged %	$\pm$15 %	$\pm$15 %	$\pm$15 %	$\pm$15 %
pH Value	5 to 8.5	5 to 8.5	5 to 8.5	5 to 8.5
Chloride Content %	0.3 %	0.3 %	0.3 %	0.3 %
Sulphate Content %	0.2 %	0.2 %	0.2 %	0.2 %
Density gm/dm^3	40 to 59	60 to 69	70 to 79	80 to 100

Foamed NR latex is applied to the back side of the coir matting by spreading.

Spreading Process



A roll of dried matting passes over the spreader bar to ensure that all creases are removed from the matting and to keep it under the correct lateral tension and it is fed under the doctor blade. The latex foam is loaded in front of the doctor blade, forming a rolling bank of material preventing expansion laterally by check plates at the end of the spreader knife and is controlled in the direction of the matting movement by the blade itself.

The angle between the blade and the matting and the distances between them control the thickness and the degree of penetration of latex foam compound. The greater the angle at which the blade meets the moving matting, the greater the degree of penetration. The backing is dried and cured by passing through a hot air oven.

Advantages

Improved appearance

Improved wear and tear

improve dimensional stability

impart anti-skid properties,

improve the laying characteristics

added heat insulation and sound absorbency

Rubberised coir fibre liners for manufacture of coir garden articles

The raw materials used for manufacture of garden coir articles are baby coir fibres and compounded natural rubber latex. The process of manufacture involves cleaning of coir fibre in willowing machine for the removal of husk particles, nose fibres and coir pith. The fibres are then fed to the sheeting machine to make fibre sheet of 2mm to 6mm thickness .Compounded natural rubber latex is applied to the coir fibre sheet by hand or automatic spraying to get rubber latex coated fiber liners or sheets.

It is then shaped to pot size of required shape manually in a mould and cured by hot pressing in a electrically or steam heated hydraulic press. The semi cured fibre pots may be kept in a vulcanization chamber for a specified period so as to get a product of desired degree of vulcanization and acquire non sticky property.

These fiber liners are used for the manufacture of different types of pots.

Advantages of pots manufactured from rubberised coir fibre liners

1. Useful for cultivation of seasonal vegetable plants.

2. No loss of manure applied in pots.

3. No chance of growth of weed/ grass in pots.

4. Retains moisture for long period.

5. Replaces non biodegradable PVC support.

6. 100 % natural, biodegradable and eco friendly product.

7. Suits growth of climbers and hanging plants.

8. Available in various sizes and shapes.

Coir baskets

These are moulded from rubberised coir fibre sheets , which are mainly available in spherical shapeThey are also available in "U" shape and conical shapes. They are used in roof gardens.

Used as liners to wire baskets for climbers and hanging plants in agri-horti-floricultures. The shaped fibre pots are supported by welded iron wire mesh, which can be kept in air by hanging it from GI wires with the help of hooks for cultivation of seasonal vegetables.

Coco Pots

Coir fibre and natural rubber latex are used for the manufacture of coco pots that are usually used as nursery bag for the seedlings, which can be directly planted without removing the 'nursery bag'. The wall thickness varies from 2 mm to 6 mm and the 2 mm thick pots are porous, the seedlings grown in these pots can be directly planted.

Tissue culture pots are available in sizes of 3" diameter x 2 $^{5}/_{8}$ Height & 4" diameter x 3$^{1}/_{2}$ height

Coco poles or Plant climbers

Coco poles are made from latex coated coir fibre sheets and mattings wrapped over wooden poles or PVC pipes . Coco poles are used as supports for ornamental plants like creepers and climbers like pepper. The covering of wooden poles with coir fibre sheet/matting help a lot in assisting the roots of climbers to make a grip to the pole while climbing upwards.

These are available with or without latex treatment. The coir fibre poles are of different sizes based on diameter and length.

There are two common varieties based on diameter (48mm and 38mm). 6 sizes based on length (50, 60,70, 80 and 90cm, 110cm). The height of the poles can be increased by joining lengths of different poles. The poles are also used separately without a pot or in combination with the pot.

Coir Fiber Liners

Made from rubberised coir fibre and are available in thickness of 4 mm and the diameter varies from 14 inch to 18 inch. It is also available with jute backing. All wall mounted coco pots come with rubberised coir liner and universal wall mount, which is ideal for attaching the baskets to fencing without the need for drilling holes.It is easy to cut the coir liner with a sharp knife to allow side planting.

Coir Fiber Disks

It is made from 2 to 6 mm thick rubberised coir sheet and used for protecting the plant from evaporation. The fibre disc is also used as weed cover around the bottom of plant preventing direct sunlight thus avoids the growth of weed under the fibre disc**.**

Hemi spheres from Coir fibre liners

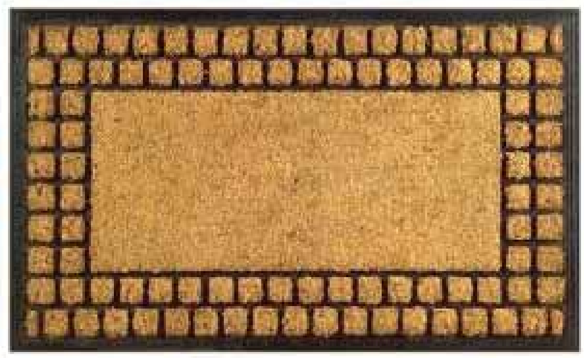
The coir fibre liners are made in to hemi spheres of varying diameter of 10”, 12”, 14”, 16”, 18” and 20” keeping the height at 5”. 16” quarter spheres are also made .

Decorative articles from coir

Cross, rings, pads, hearts, rhombus, balls etc. can be fabricated from coir fibre bonded with rubber latex compound

Rubber backed coir mats/ Matting Tiles

Rubber backed coir products finds extensive use as flooring material. It is manufactured by hot pressing of compounded rubber based on natural, synthetic and reclaimed rubber or its blends on the back side of coir products such as mats/matting. Rubber and various ingredients for backing are mixed on a two roll mill and allowed to mature over night. The compound so prepared is made into sheet of desired thickness on a mixing mill or calendar.



Prepare blanks of compounded rubber sheet of size equal to that of the coir material to be backed. The mould is heated and sprayed with a suitable mould releasing agent and the blank rubber compound sheet is kept in the mould and the coir material to be backed is placed over the blank rubber sheet. The combination is then placed in between the platens of a steam/ electrically heated hydraulic press/hand fly press. It is then pressed at the appropriate temperature and pressure for the specified time. The press is opened and the product removed from the mould, cooled and trimmed. Backing of rolls of coir mattings can be achieved by calendaring process using a three roll or four roll calendars. Provision should be taken not to tamper the pile structure / texture of coir matting during backing with rubber compound.

Advantages of Rubber Backed Coir Mats/ Matting Tiles

1. Ease of laying.

2. Gives a non-slip finish.

3. Improved resistance to creasing.

4. Improved wear resistance, insulation and comfort.

5. Good performance and flexibility of manufacture.

6. Protection against damp, dirt and abrasion.

7. Greater dimensional stability.

8. Prevents fraying-off edges.

9. Insulation against electricity

Fire retardant finishes to Rubberised Coir

Since coir is used in environment with possibilities of the fire hazards, a certain degree of flame retardance is desired in the material for its application in selected areas. Fire retardant treatment shall reduce combustibility, flame spread rate and stop the burning of the product when the source of ignition is removed.

The following parameters should be taken into consideration for imparting fire retardancy to rubberised coir

1. The treatment must not adversely affect the physical properties

2. The treated fibre must be compatible with the binder composition

3. The treatment must not impair the binding properties of the fibre

4. The component should be un- reactive towards other additives and resistant to the usual after treatments such as vulcanization.

5. The additive should be devoid of toxic and allergic effects.

6. The fire retardant additive should be capable of imparting a high degree of resistance to both after flaming and after glowing

7. Easy to apply and inexpensive

Flamcel C solution alone was sprayed to both the sides of rubberized coir without any dilution and a mixture of Flamcel C, Firepac and Dri one in the proportion of 1:1:1(Flamcel C is a proprietary chemical of Britacel Silicones Ltd, Mumbai, Dri one of Desert Research Institute, USA, Firepac of Plastcizers & Allied Chemicals, Delhi) and the treated rubberized coir was tested for flammability as per IS:5641 by camphor pellet and the result is given below.

Testing of rubberized coir –IS: 5641

Sl.No	Description of application on rubberized coir	Charred area cm^2
1	Rubberized coir with flamcel C solution without dilution	1.3
2	Rubberized coir sprayed with a mixture of Flamcel C Firepac and Dri one (1:1:1 solution)	1.2
3	Untreated rubberized coir	2.1

Both the treatment improved the flame retardant characteristics as seen from the above table

कयर बोर्ड

COIR BOARD

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