Various Industrial Applications of Hemp, Kinaf, Flax and Ramie Natural Fibres

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***Abstract*—The materials chosen for structural upgradation must, in addition to functional efficiency and increasing or improving the various properties of the structures, should fulfil some criterion, for the cause of sustainability and a better quality. For example, these materials should not pollute the environment and endanger bioreserves, should be such that they are self sustaining and promote self-reliance, should help in recycling of polluting waste into usable materials, should make use of locally available materials, utilise local skills, manpower and management systems, should benefit local economy by being income generating, should be accessible to the ordinary people and be low in monetary cost. Besides improving the strength of the structure using FRPs as the raw material, it is also necessary to make use of local materials in construction. So far the work on construction. So far the work on retrofitting of structures is confined to using of carbon, glass or aramid fibres etc, very little work is being imparted in improving structures using naturally available materials, or natural fibres. The application of composites in structural facilities is mostly concentrated on increasing the strength of the structure with the help of artificial fibres and does not address the issue of sustainability of these raw materials used for strengthening purposes. In an expanding world population and with the increase of the purchasing potentials, the need for raw materials required for structural strengthening, that would satisfy the demand on world market is rapidly growing. In times when we cannot expect the fibre reinforced polymer prices to come down, with the consumption growing day by day. Also waste disposal has become one of the major problems in modern cities. At present there are two major methods in practice to dispose wastes. One is land filling and the other is burning. First one requires more valuable land and second one pollutes the environment. So, alternate methods to dispose solid waste should be found. New materials that would be cheaper and at the same time offer equal or better properties have to be developed. We have enough natural resources and we must keep on researching on these natural resources. Development of plant fibre composites has only begun. Among the various natural fibres such as, sisal fibres, bamboo fibres, coir fibres and jute fibres are of particular interest as these composites have high impact strength besides having moderate tensile and flexural properties compared to other lignocellulosic fibres. Among the various natural fibres, sisal fibre reinforced composite, bamboo fibre reinforced composite, coir reinforced composite and jute fibre reinforced composite are of particular interest as these composites have high impact strength besides having moderate tensile and flexural properties compared to other lignocellulosic fibres. Hence encouragement should be given for the use of natural fibres such as sisal fibres, bamboo fibres, coir fibres and jute fibres which are locally available materials, in the field of civil engineering. Also by considering the case of waste disposal, here an attempt is made to study the possibilities of reusing the sisal fibres, bamboo fibres, coir fibres and jute fibres which not only has various applications but also helps to solve the problem of waste disposal atleast to a small extent. Economic and other related factors in many developing countries where natural fibres are abundant, demand that scientists and engineers apply appropriate technology to utilize these natural fibres as effectively and economically as possible for structural upgradation and also other purposes for housing and other needs and also for various other applications etc.**

***Index Terms*—Natural Fibres, Sustainable Development, Sisal fibres, Bamboo fibres, Coir fibres and Jute fibres**

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I. Introduction

A judicious combination of two or more materials that produces a synergistic effect. A material system composed of two or more physically distinct phases whose combination produces aggregate properties that are different from those of its constituents. Composites are hybrid materials made of a polymer resin reinforced by fibres, combining the high mechanical and physical performance of the fibres and the appearance, bonding and physical properties of polymers, the short and discontinuous fibre composites are responsible for the biggest share of successful applications, whether measured by number of parts or quantity of material used.

A composite in this respect is a compound between a polymer (such as polyester or PP) and a fibrous material (such as glass, carbon or natural fibres). Composite products have good mechanical properties per unit weight, are durable and their technologies allow the manufacture of complex and large shapes. For these applications the substitution of industrial fibres with natural fibres could be considered. Many natural fibres traditionally employed in weaving, sacking and ropes; present various potentials to be used as reinforcement elements in composites. With development of improved materials with increasing costs, now a days cost reduction during manufacturing and operation are the main technology drivers. Latest development is the use of composites to protect man against fire and impact and a tendency to a more environmental friendly design, leading to the reintroduction of natural fibres in the composite technology, natural fibres. They can be formed on site into complicated shapes and can also be easily cut to length on site. These include wood fibres, jute, sisal, coconut, bamboo and banana leaves. Such fibres could be added alone or in hybrid composites, in partial substitution for industrial fibres.

Natural fibres such as hem, kinaf, flax and ramie can be used successfully in composite components in order to realise reduction of weight and cost. These fibres are renewable, non-abrasive to process equipment, and can be incinerated at the end of their life cycle for energy recovery as they possess a good deal of calorific value. They are also very safe during handling, processing and use. The distinctive properties of natural fibre reinforced polymers are improved tensile and bending strength, greater ductility and greater resistance to cracking and hence improved impact strength and toughness. By changing the direction of the fibres in the resin, the material properties can be tailored to the external loads. To optimize the construction multiple adjusted layers (laminae) can be used to form a laminate. By this joining, the poor capabilities and drawbacks of the individual components disappear. By this joining, the poor capabilities and drawbacks of the individual components disappear. For instance, composites combine a high stiffness and strength with a low weight and their corrosion resistance is often excellent. Composites have worked their way up amongst wood and metal due to their outstanding price performance ratio during a lifetime. A powerful approach in improving this ratio is to minimise the steps required from raw material to end product.

The use of residues from the processing of vegetable fibre in civil construction could contribute to the increase of income in the agricultural industry, together with the agricultural producers. Studies are continuing to establish the durability of vegetable fibre reinforcement, which is normally attacked by the alkaline surrounding of Portland cement matrix. The improvement of composites reinforced by vegetable rejects can still lead to a sustainable development in predominantly agricultural regions. The studies on sugar cane bagasse show the viability of composites as a substitute of wood chip board. Jute, curaua, sisal, coconut and banana fibres are the most studied as reinforcement in cementitious composites. There are other vegetable fibres which present great potentials for this purpose. Natural fibres are generally lignocellulosic in nature, consisting of helically wound cellulose micro fibrils in a matrix of lignin and hemicellulose. According to a Food and Agricultural Organization survey, Tanzania and Brazil produce the largest amount of sisal. Henequen is grown in Mexico. Abaca and hemp are grown in the Philippines. The largest producers of jute are India, China, and Bangladesh. Presently, the annual production of natural fibres in India is about 6 million tons as compared to worldwide production of about 25 million tons. The mechanical properties of a natural fibre-reinforced composite depend on many parameters, such as fibre strength, modulus, fibre length and orientation, in addition to the fibre-matrix interfacial bond strength. A strong fibre-matrix interface bond is critical for high mechanical properties of composites. A good interfacial bond is required for effective stress transfer from the matrix to the fibre whereby maximum utilization of the fibre strength in the composite is achieved. Modification to the fibre also improves resistance to moisture induced degradation of the interface and the composite properties. In addition, factors like processing conditions/techniques have significant influence on the mechanical properties of fibre reinforced composites.

II. Different Types of Natural Fibre

A. Hemp

Hemp is a member of the *Cannabaceae* family and is a plant which produces bast fibres. Bast fibres are soft woody fibres obtained from the stems of dicotyledonous plants. Hemp originated in Central Asia and was grown for its fibres since 2800 BC. It was cultivated in the Mediterranean countries during the middle Ages. Hemp (also known as *Cannabis*) was one of the first plants to be cultivated by the human race and was previously considered to be one of the most important agricultural crops. The Celts considered hemp to be a mystical plant and Queen Elizabeth I decreed that all farmers were obliged to grow hemp on their farms. Until the 1800s, *Cannabis* was used to produce rope, cloth, food, lighting oil and medicine and was one of the main cultivated plants throughout the western world. Guttenberg's first Bible was published upon hemp paper and currently hemp fibres are used to manufacture bank notes. Hemp is an extremely useful plant, as it provides fibres, oil and hardwood. Its fibres are very strong with a tensile strength of 550 – 900 MPa and were valued hugely before the development of plastic fibres from petrochemicals. From the 1930s, *Cannabis sativa* disappeared from the world markets. With the increase of petrochemical fibres, the importance of natural fibres declined and as a result *Cannabis* became a less important crop. The banning of the plant in the US coincided with the release of the first plastic fibres from Dupont Pharmaceuticals. At the time of the US banning of *Cannabis sativa*, a Dupont senator was a direct advisor to the president and advocated the ban, on grounds of drug misuse. In 1937, a US tax made growing hemp (the drug-free form of *Cannabis sativa)* prohibitively expensive preventing any further growth of the plant in America. Ranalli states that 'The prohibition of *Cannabis* drugs has led to the prohibition of *Cannabis* cultivation in general, and the historically important uses of *Cannabis* have been largely forgotten…' The plant itself can be grown without artificial fertilisers and weeds don't stand a chance because hemp covers the entire ground within 4 weeks. The production is very labour intensive, especially the separation of the fibres from the bast. After mowing, the stems are bundled and dried. The seeds are removed by threshing and the stems are dew or water retted, dried and hackled to remove the fibres. Breaking softens the fibres and the top and bottom (bad) parts are removed. A Hemp yarn is strong and has of all natural fibres the highest resistance against water, but it shouldn't be creased excessively to avoid breakage. As hemp is a plan not require pesticides and requires little fertilising. A hemp crop can be grown in Ireland in roughly 100 days. One hectare of hemp produces 3.5 tons of hurds. The current decortications process of sepahemp into its separate parts of long fibres and woody hurds results in the hurds as a by-product. The only direct energy required for processing is inspection of the material, packaging and transportation. Hurds are now available from a large hemp producer in England (Hemcore), and there are several suppliers throughout Ireland. This material has negative impact on the environment in terms of CO_2 production. The fibre is used for the production of rope, fishing nets, paper, sacks, fire hoses and textile. Fibre stems drying on the field separating the fibres from the stem.

Throughout the world, hemp is cultivated commercially for its strong, valuable fibres and oil. These hurds are a natural by-product after the plant has been used for other purposes. The hemp was used for two main roles. Firstly, hemp hurds were mixed with a hydraulic lime binder as an aggregate; secondly, fibres were added as a tensile reinforcement in a lime/hemp hurd mix. This investigation was designed to examine the strength of a typical lime/hemp hurd mix and to determine if hemp fibres can strengthen it. Hemp however has certain distinct advantages. It is stronger than sisal and ramie, and it is much cheaper to grow and process than flax. Hemp also grows with a much higher yield per acre than flax.

Properties of this fibre are as follows :

Density [kg/m3]	1480
Tensile strength [N/mm2]	550-900
Stiffness [kN/mm2]	70
Moist absorption [%]	8

Available countries:-

Yugoslavia, china, Nigeria, Guyana, Siera Leone, India

1) *Advantages*

a) Its fibres are very strong with a tensile strength of 550 – 900 MPa

b) A Hemp yarn is strong and has of all natural fibres the highest resistance against water.

c) Hemp is a plant which does not require pesticides and requires little fertilizing.

d) Its growth is faster than any other any other natural fibre.

e) Hemp requires less moisture to grow than kenaf.

f) Hemp's fibre-bundles are stronger and tougher than those of kenaf, generally comparable to varieties of flax, and most other known fibre species.

g) Hemp is generally pest resistant, drought resistant, and light frost resistant.

h) With proper leaf removal, hemp has low net nutrient requirements and requires minimal cultivation.

i) Hemp provides greater fibre yields in areas generally north of the 40th latitude than most other fibre crops, generally surpassing flax by 10%.

2) *Disadvantages*

a) The production is very labour intensive, especially the separation of the fibres from the bast.

b) It shouldn't be creased excessively to avoid breakage.

c) Restrictions of its growth and cultivation in North America, especially in the United States.

d) Lower fibre yields than kenaf and other tropical species in the warmer portions of the United States and more southerly regions.

e) Lower bast fibre portions relative to kenaf and flax.

3) *Applications*

a) Hemp is used to produce rope, cloth, food, lighting oil and medicine.

b) Currently hemp fibres are used to manufacture bank notes.

c) These are valued hugely before the development of plastic fibres from petrochemicals.

d) Hemp hurds can be mixed with hydraulic lime binder as an aggregate

e) Hemp fibres were added as a tensile reinforcement in a lime/hemp hurd mix.

B. *Kenaf*

Kenaf [Etymology: Persian] *Hibiscus cannabinus*, is a plant in the Malvaceae family. *Hibiscus cannabinus* is in the genus *Hibiscus* and is probably native to southern Asia, though its exact natural origin is unknown. The name also applies to the fibre obtained from this plant. Kenaf is one of the allied fibres of jute and shows similar characteristics. Other names include Bimli, Ambary, Ambari Hemp, Deccan Hemp, and Bimlipatum Jute. It is labelled as Gongoora in Indian, Korean, American food and groceries chains in the United States. Gongoora is from Telugu. It is a high-yielding tropical plant traditionally grown for the long, strong bast fibres that develop in the bark layer of the stem. Cultivation spread internationally in the early to mid-twentieth century, but interest waned, particularly in developed counties, as raw materials for cordage and related products shifted from biological to petrochemical sources. Concerns over rising costs, unstable supply, and negative environmental impact of fossil fuels are promoting renewed interest in traditional fibre crops. Kenaf is a multipurpose crop with various harvestable components: leaves and tender shoots are suitable for forage; the woody core has attributes for forest-product substitutes, absorbents, and structural materials; and seeds have an oil and protein composition similar to cotton seed. The bast fibres, however, remain the primary economic incentive to grow kenaf. Beyond cordage, bast fibres are expanding into new markets of mouldable, nonwoven fabrics, and reinforced composite materials in automotive, aerospace, packaging and other industrial applications. This trend is in part due to the fibre's physical properties of light weight, competitive tensile strength and stiffness, and vibration damping properties, and also due to the fibre being a renewable and biodegradable resource. Nonwoven materials made of kenaf or other natural fibres blended with polyester or polypropylenes are efficient sound absorbers and can meet industry specifications of flammability, and odour and mildew resistance. It is an annual or biennial herbaceous plant (rarely a short-lived perennial) growing to 1.5-3.5 m tall with a woody base. The stems are 1–2 cm diameter, often but not always branched. The leaves are 10–15 cm long, variable in shape, with leaves near the base of the stems being deeply lobed with 3-7 lobes, while leaves near the top of the stem are shallowly lobed or unlobed lanceolate. The flowers are 8–15 cm diameter, white, yellow, or purple; when white or yellow, the centre is still dark purple. The fruit is a capsule 2 cm diameter, containing several seeds. Kenaf was grown under two different conditions, at an average temperature of 22 °C (condition A) and at an average temperature of 30 °C (condition B). The geographical locations of conditions A and B are Miyagi Prefecture and Ehime Prefecture in Japan, respectively. The height of the kenaf was measured weekly. The effect of cultivation conditions on the tensile strength of the kenaf fibres also was examined. Furthermore, to investigate the effect of location of the fibre on the plant (from root to tip) on tensile strength, the kenaf was divided into four sections (every 500 mm from the ground) and the tensile properties compared.

Properties of this fibre are as follows :

Density [kg/m3]	1320
Tensile strength [N/mm^2]	260
Moist absorption [%]	10-12

Available countries:-

India, Bangladesh, United States of America, Indonesia, Malaysia, South Africa, Viet Nam, Thailand.

1) *Advantage*

a) Rapid growth: Kenaf reaches 12-18 feet in 150 days, while southern pine (A species commonly grown on tree plantations) must grow 14 to 17 years before it can be harvested.

b) High yield: Kenaf also yields more fibre per acre than southern pine producing 5-10 tons of dry fibre per acre, or approximately 3 to 5 times as much as southern pine.

c) Exceptional papermaking characteristics: Less chemicals, heat and time are required to pulp kenaf fibres because they are not as tough as wood pulp and contain less lignin.

d) It is a bast fibre with good length.

e) This fibres are very good in tension.

f) Easily available and low cost fibres.

g) Bast plants have a relatively low specific gravity of 0.28 – 0.62, yielding an especially high specific strength, i.e. strength to weight ratio.

h) Genetic strains have been developed which yield 35% or greater bast portions. This is a relatively high proportion.

2) *Disadvantage*

a) Rotations at least every other year generally required.

b) Lack of related agricultural infrastructure.

c) Relatively high absorption of moisture in core portion.

d) Diminished board properties when using core for particleboard.

e) Difficulty in handling long fibre bundle lengths for processing.

f) Difficulty in applying binder to long fibre bundle lengths.

g) Low productivity in cooler climates. Its growing season can be as short as 90 – 120 days, and consequently it will grow in almost any region of North America if sufficient moisture is available.

h) High moisture requirements. 600 mm, (23.6 in) of water is preferable during its growing cycle of 120-150 days,

3) *Applications*

a) The kenaf leaves are consumed in human and animal diets.

b) The bast fibre was used for bags, cordage, and the sails for Egyptian boats.

c) The uses of kenaf fibre have been rope, twine, coarse cloth.

d) Uses of kenaf fibre include engineered wood, insulation, clothing-grade cloth, soil-less potting mixes, animal bedding, packing material, and material that absorbs oil and liquids.

e) It is also useful as cut bast fibre for blending with resins for plastic composites, as a drilling fluid loss preventative for oil drilling muds, for a seeded hydromulch for erosion control.

f) Kenaf can be made into various types of environmental mats, such as seeded grass mats for instant lawns and moldable mats for manufactured parts and containers.

g) Kenaf is also used for producing papers.

C. *Flax*

Flax (also known as common flax or linseed) (binomial name: Linum usitatissimum) is a member of the genus Linum in the family Linaceae. It is native to the region extending from the eastern Mediterranean to India and was probably first domesticated in the Fertile Crescent. Flax was extensively cultivated in ancient Ethiopia and ancient Egypt. In a prehistoric cave in the Republic of Georgia, dyed flax fibres have been found that date to 30,000 BC New Zealand flax is not related to flax but was named after it, as both plants are used to produce fibres. Flax is an erect annual plant growing to 1.2 m (3 ft 11 in) tall, with slender stems. The leaves are glucose green, slender lanceolate, 20–40 mm long and 3 mm broad. The flowers are pure pale blue, 15–25 mm diameter, with five petals; they can also be bright red. The fruit is a round, dry capsule 5–9 mm diameter, containing several glossy brown seeds shaped like an apple pip, 4–7 mm long. Flax fibres are amongst the oldest fibre crops in the world. The use of flax for the production of linen goes back at least to ancient Egyptian times. Dyed flax fibres found in a cave in Dzudzuana (prehistoric Georgia) have been dated to 30,000 years ago.[18] Pictures on tombs and temple walls at Thebes depict flowering flax plants. The use of flax fibre in the manufacturing of cloth in northern Europe dates back to Neolithic times. In North America, flax was introduced by the Puritans. Currently most flax produced in the USA and Canada are seed flax types for the production of linseed oil or flax seeds for human nutrition. Flax fibre is extracted from the bast or skin of the stem of the flax plant. Flax fibre is soft, lustrous and flexible; bundles of fibre have the appearance of blonde hair, hence the description "flaxen". It is stronger than cotton fibre but less elastic. Flax is harvested for fibre production after approximately 100 days, or a month after the plant flowers and two weeks after the seed capsules form. The base of the plant will begin to turn yellow. If the plant is still green the seed will not be useful, and the fibre will be underdeveloped. The fibre degrades once the plant is brown. There are two ways to harvest flax, one involving mechanized equipment (combines), and a second method, more manual and targeted towards maximizing the fibre length. The mature plant is cut with mowing equipment,

similar to hay harvesting, and raked into windrows. When dried sufficiently, a combine then harvests the seeds similar to wheat or oat harvesting. The amount of weeds in the straw affects its marketability, and this coupled with market prices determined whether the farmer chose to harvest the flax straw. If the flax was not harvested, it was typically burned, since the straw stalk is quite tough and decomposes slowly (i.e., not in a single season), and still being somewhat in a windrow from the harvesting process, the straw would often clog up tillage and planting equipment. It was common, in the flax growing regions of western Minnesota, to see the harvested flax straw (square) bale stacks start appearing every July, the size of some stacks being estimated at 10-15 yards wide by 50 or more yards long, and as tall as a two-story house. The mature plant is pulled up with the roots (not cut), so as to maximize the fibre length. After this, the flax is allowed to dry, the seeds are removed, and is then retted. Dependent upon climatic conditions, characteristics of the sown flax and fields, the flax remains on the ground between two weeks and two months for retting. As a result of alternating rain and the sun, an enzymatic action degrades the pectins which bind fibres to the straw. The farmers turn over the straw during retting to evenly ret the stalks. When the straw is retted and sufficiently dry, it is rolled up. It will then be stored by farmers before starting to extract fibres.
Available countries:-
India, Bangladesh, United States of America,Canada, China, Ethiopia, Russia, Ukraine, French, Argentina.

1) *Advantage*
   a) Flax fibre is soft, lustrous and flexible.
   b) Flax is easy to grow.
   c) It is a bast fibre with good length.
   d) These fibres are very good in tension.
   e) Easily available and low cost fibres.
2) *Disadvantage*
   a) Flax is susceptible to a wide variety of fungal diseases, blights and rusts.
   b) Both Pond and Stream retting were traditionally used less because they pollute the waters used for the process.
   c) Difficulty in handling long fibre bundle lengths for processing.
3) *Applications*
   a) The best grades are used for linen fabrics such as damasks, lace and sheeting.
   b) Coarser grades are used for the manufacturing of twine and rope.
   c) Various parts of the plant have been used to make fabric, dye, paper, fishing nets, hair gels, and soap.
   d) The use of flax fibre for manufacturing fabrics for garments dates back to Neolithic times.
   e) Sprouts are used in salads.
   f) The oil from the seeds makes linseed oil, and can be used in cooking.
   g) Can be ground into a low carbohydrate meal for making breads and doughs.
   h) Are used in herbal teas.
   i) The medicinal uses of Flax Promotes heart health, Lowers cholesterol, Protects against strokes, Lowers blood pressure, Used for constipation, Helps guard against breast cancer and other cancers.

D. Ramie

Ramie (pronounced Ray-me) is one of the oldest vegetable fibres and has been used for thousands of years. It was used in mummy cloths in Egypt during the period 5000 - 3000 BC, and has been grown in China for many centuries. Ramie (Boehmeria nivea), commonly known as China grass, white ramie, green ramie and rhea, is one of the group referred to as the bast fibre crops. The ramie plant is a hardy perennial belonging to the Urticaceae or Nettle family, which can be harvested up to 6 times a year. It produces a large number of unbranched stems from underground rhizomes and has a crop life from 6 to 20 years. It possesses highest strength and length, good durability and absorbency with excellent lustre. These remarkable characters make it rather more suitable for use in the manufacture of wide variety of textiles and cordage products. However, despite its unique quality, ramie has received comparatively less prominence in the calendar of important crops of the world. Recently with the availability of more technical know how, the crop has started getting slightly more importance and the countries like China, Brazil and the Philippines have come forward with commercial cultivation. Besides, the other countries like Japan, Taiwan, Indonesia, Vietnam, Korea, Columbia, Malaysia and France have also started cultivating ramie in a limited scale. Ramie is a plant of perennial nature, which sends up a large number of straight slender stalks. These stalks grow upto the length of about 150 to 200 cm with a diameter of 12 to 20 mm. depending upon the growing conditions. The shoot consists of several long and short serial sterns each called "Cane". Several canes together form a "clump". The leaves are alternate, long petioled and appear on the upper part of the stalks. They are heart shaped, broadly ovate and abruptly acuminate having a width of nearly 50 to 130 mm. and length varying in between 100 to 150 mm. with finally serrated margins. Leaves contain nearly 20 to 24% protein. The leaves are hairy with felty hairs and with white under face in case of B. nivea and with green undersurface in case of B. utilis. The flowers are greenish white in colour, born in declinate clusters in the axils of the leaves. Male and female flowers are found on the same stalk. The female flowers are in auxiliary panicles, unisexual with five sepals and no petals. They are found on the upper part of the stalk. They have one celled, one seeded ovary and a slender style, hairy on one side. The male flowers are arranged on the lower part, have five stamens and a rudimentary ovary. The male flowers open first and the flowers are wind pollinated. Seeds are produced in great number. They are very small in size and weigh nearly 7000 seeds per gram. The plants have rhizomatous roots which contain storage roots, small fibrous roots and rhizomes (sometimes also called as reproductive or lateral roots). Ramie grows well in the areas having good rainfall and warm climate. On an average annual yield of fibre may vary from 1200 kg to 1800 kg/ha. The textile value of ramie fibre is remarkable because of its silky, lustre, unparallel strength, durability and its suitability as blend with all natural and manmade fibres. Ramie has exceptionally long ultimate fibre cells which range from 120 to 150 mm. approximately. This is nearly six times more than cotton, ten times more than flax and eight times more than silk. Ramie fibre is extremely white in colour and does not change colour with exposure to sunlight etc. It can absorb moisture and also give it up quickly with no shrinking and stressing effects on it. Ramie fibre also resists the action of chemicals better than other fibres and has high resistance to the effects of bacteria and fungus including mildew. It has, however, been observed that the undegummed fibre is sometimes affected by some organisms in warm and humid conditions. About its absorbency quality, Coss and Tayler (1948) also found that upon total immersion it can absorb water 100% within 10 mts. and 195% in 72 hours only. The fibre also takes the dye readily. The specific gravity of fibre ranges from 1.50 to 1.55.

Available countries:-

China, Brazil, Philippines, Japan, Taiwan, Indonesia, Vietnam, Korea, Columbia, Malaysia and France.

1) Advantage

a) Resistant to bacteria, mildew, alkalis, rotting, light and insect attack.
b) Extremely absorbent (this makes it comfortable to wear)
c) Dyes fairly easy.
d) Natural stain resistance.
e) Increases in strength when wet.
f) Withstands high water temperatures during laundering.
g) Smooth lustrous appearance improves with washing.
h) Keeps its shape and does not shrink.
i) Strong and durable (It is reported to have a tensile strength eight times that of cotton and seven times greater than silk).
j) Can be bleached.

2) Disadvantage

a) Low in elasticity.
b) Lacks resiliency.
c) Low abrasion resistance.
d) Wrinkles easily.
e) Stiff and brittle.
f) Necessary de-gumming process.
g) High cost (due to high labour requirement in production, harvesting and decortications.)

3) Applications

a) Despite its strength, ramie has had limited acceptance for textile use. Ramie is used to make such products as industrial sewing thread, packing materials, fishing nets, and filter cloths Sewing threads, Handkerchiefs, Parachute fabrics, Woven fire hoses, Narrow weaving Canvas, and Filter cloth etc
b) It is also made into fabrics for household furnishings (upholstery, canvas) and clothing, frequently in blends with other textile fibres (for instance when used in admixture with wool, shrinkage is reported to be greatly reduced when compared with pure wool.)
c) Shorter fibres and waste are used in paper manufacture.
d) Apparel dresses, suits, skirts, jackets, pants, blouses, shirts, children wear, mixed with cotton in knitted sweaters .
e) Home fashion curtains, draperies, upholstery, bedspreads, table linens, sheets, dish towels .
f) When used in a mixture with wool, shrinkage is reported to be greatly reduced when compared with pure wool.
g) Short waste fibres are used for the production of high quality papers, such as bank notes & cigarette papers.
h) As ramie takes up phosphorous, it is potentially useful for cleaning up the Everglades. This region suffers from a nutrient overload from the sugar industry.

III. Comparison of Various Types of Natural Fibres

A. Applicational differences

Names of the fibres	Applications
Hemp	1. Hemp is used to produce rope, cloth, food, lighting oil and medicine. 2. Currently hemp fibres are used to manufacture bank notes. 3. These are valued hugely before the development of plastic fibres from petrochemicals. 4. Hemp hurds can be mixed with a hydraulic lime binder to act as an aggregate 5. Hemp fibres were added as a tensile reinforcement in a lime/hemp hurd mix.
Kenaf	1. The kenaf leaves were consumed in human and animal diets. 2. The bast fibre was used for bags, cordage, and the sails for Egyptian boats. 3. The uses of kenaf fibre have been rope, twine, coarse cloth. 4. Uses of kenaf fibre include engineered wood, insulation, clothing-grade cloth, soil-less potting mixes, animal bedding, packing material, and material that absorbs oil and liquids. 5. It is also useful as cut bast fibre for blending with resins for plastic composites, as a drilling fluid loss preventative for oil drilling muds, for a seeded hydromulch for erosion control. 6. Kenaf can be made into various types of environmental mats, such as seeded grass mats for instant lawns and moldable mats for manufactured parts and containers. 7. Kenaf is also used for producing papers.
Flax	1. The best grades are used for linen fabrics such as damasks, lace and sheeting. 2. Coarser grades are used for the manufacturing of twine and rope. 3. Various parts of the plant have been used to make fabric, dye, paper, fishing nets, hair gels, and soap. 4. The use of flax fibre for manufacturing fabrics for garments dates back to Neolithic times. 5. Sprouts are used in salads. 6. The oil from the seeds makes linseed oil, and can be used in cooking. 7. Can be ground into a low carbohydrate meal for making breads and doughs. 8. Are used in herbal teas. 9. The medicinal uses of Flax Promotes heart health, Lowers cholesterol, Protects against strokes, Lowers blood pressure, Used for constipation, Helps guard against breast cancer and other cancers.

Ramie	1. Despite its strength, ramie has had limited acceptance for textile use. 2. Ramie is used to make such products as industrial sewing thread, packing materials, fishing nets, and filter cloths. 3. It is also made into fabrics for household furnishings (upholstery, canvas) and clothing, frequently in blends with other textile fibres (for instance when used in admixture with wool, shrinkage is reported to be greatly reduced when compared with pure wool.) 4. Shorter fibres and waste are used in paper manufacture. 5. Apparel dresses, suits, skirts, jackets, pants, blouses, shirts, children wear, mixed with cotton in knitted sweaters 6. Home fashion curtains, draperies, upholstery, bedspreads, table linens, sheets, dish towels, Sewing threads, Handkerchiefs, Parachute fabrics, Woven fire hoses, Narrow weaving, Canvas Filter cloth. 7. When used in a mixture with wool, shrinkage is reported to be greatly reduced when compared with pure wool. 8. Short waste fibres are used for the production of high quality papers, such as bank notes & cigarette papers. 9. As ramie takes up phosphorous, it is potentially useful for cleaning up the Everglades. This region suffers from a nutrient overload from the sugar industry.

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