A Review on Jute Geotextile and its Geo-Technical Applications with respect to Environmental Concern

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Abstract— **Natural fibres are gradually emerging as essential ingredients of various types of textiles in view of increasing global concerns about environmental degradation. Reduction of carbon foot print in constructions is currently attracting global attention warranting innovations in construction technology with stress on eco-congruity. In this context increasing use of eco-concordant materials made of natural fibres to the extent feasible in constructions has assumed significance. Textile Technology is at the same time poised to take innovative turns by manufacturing products that could meet the technical requirements on the one hand and could help maintain eco-congruity on the other. Till date man-made (artificial polymer-based) fibres have a dominant role for its many advantages excepting the aspect of eco-congruity. Jute, besides its unique features, excels other natural fibres in availability and spinnability. There has been substantial research on technological innovations of Jute in the recent past mostly related to non-technical applications. With newer avenues in technical applications opening up of late, the need for continuing R & D has become a necessity. Development of Jute Geotextiles (JGT) in Geotech category of Technical Textiles is a pointer in this direction. Besides its effectiveness in carbon sequestration and eco-compatibility from cradle-to-grave, diverse applications of JGT are being conceptualized with thrust on R & D as unique technical attributes of Jute can meet most of the technical requirements needed for the major geo-technical applications. This paper brings out the physical characteristics of Jute fibre and some of the innovative R & D exercises executed so far.**

Keywords- carbon foot print; eco-congruity; jute geotextiles; geo-technical applications.

I. INTRODUCTION

Use of geotextiles (now termed geosynthetics encompassing both natural & man-made geotextiles) to address a variety of soil-related problems in civil engineering is now an accepted and proven technology (1). Extensive R & D on man-made (synthetic) geotextiles has led to development of new varieties for specific applications according to the nature and severity of problems. Interestingly, the concept of making geosynthetics from man-made fibres such as nylon, polyester, polyamide and similar petro-chemical derivatives which originated in the first half of 1950s owes its origin to natural contrivances made ages ahead for soil erosion control(2). Making of geosynthetics from natural fibres such as Jute & coir is thus something like switching back to the original roots of a concept.

This paper aims at introducing natural geotextiles with special reference to Jute Geotextiles (JGT) and presents an overview of the emerging technology.

II. SUITABILITY OF NATURAL FIBRES AS GEOTEXTILES

Geosynthetics in general call for adequate tensile strength, good spinnability and weavability in machines (for large scale production), drapability (loosely, flexibility) and retention of tensile strength for at least two years (3). Natural geosynthetics generally cannot match their man-made counterpart in the upper range of tensile strength. Usually tensile strength of 25 kN/m is sufficient to address the majority of the requirements. Most of the natural fibres can meet this requirement. Precise porometry features in woven geosynthetics depend on spinnability and weavability of the yarn. Coir for instance is a strong and rigid fibre but low in spinnability and weavability. As woven geotextiles are designed in keeping with average grain size diameter of soil on which it is to be laid and may need to have pore size as low as 100 μ in some cases, only fine fibres such as Jute can address the requirement which is only second to cotton in this respect (4). The foremost concern in respect of all natural geotextiles is about availability of fibres in sufficient quantities for commercial production of geosynthetics. Only Jute and coir are available in abundance. Other natural fibres at the existing rate of production are not in a position to meet the demand of geotextiles.

III. Jute Geotextiles (JGT) vis-à-vis Man-made Geotextiles

Man-made (synthetic) fibres are basically thermoplastics such as polyamide, polyester, polyethylene, polypropylene, PVC and the like. Fabrics made of such synthetic polymers were initially used as apparels and fabrics basically for internal use. Long durability of synthetic fibres as well as their very high tensile strength, ease of production and technical flexibility led to development of geotextiles first in the Netherlands in 1953 for geotechnical applications and till date is accepted as the most technically effective engineering fabric for addressing geotechnical problems.

Interestingly, long before the concept of making fabrics with man-made ingredients took shape, a section of engineers in Scotland and India thought of laying Jute Hessian on roads for strengthening. The first such experiment was carried out at Dundee, Scotland in 1920 and later, on Strand Road, Kolkata, India in 1934 by Bengal PWD (5). Jute Hessian was also reportedly used in World War II in Myanmar with satisfactory results. The trials unfortunately were not monitored and followed up in right earnest and potential of Jute in road construction remained unrealized for long. The trials deserve to be treated as the first use of Jute fabrics as geotextile. The U.S.A. started using open weave Jute Geotextiles (JGT) under brand names of “Soil Saver”, “Anti-wash” principally for slope erosion control which, till date, remains a major exportable product of India. Concerted efforts to manufacture, use and promote JGT started in early 1990s (6). Environmentally man-made geotextiles have disadvantages which is why natural geotextiles are gradually being preferred in less critical areas globally.

IV. Specialities of Jute

Jute fibres possess good pliancy and render a high degree of flexibility and fineness to fabric construction (table 1). High initial modulus, consistency in tenacity (depends on thickness of the filament), high torsional rigidity and low percentage of elongation-at-break make Jute a suitable fibre for geosynthetics (7). The other remarkable property of Jute is its capacity to absorb water because of its high cellulosic content. Jute fibres/yarns can absorb water up to about 500% of their dry weight. Hygroscopic property of Jute is the highest among all fibres—natural & of course man-made. Jute Geotextiles can be manufactured conforming to customized specifications in regard to porometry, tensile strength, permittivity (passage of water across the fabric) & transmissivity (transmission of water along the fabric) which are comparable to man-made geotextiles as shown in table 2 below. Puncture strength and burst strength of Jute Geotextiles are also close to man-made geosynthetics. Besides, JGT has a distinct environmental edge.

TABLE I. Chemical Composition of Some Natural Fibres

Constituents	**Fibres**					
	Flax	*Jute*	*Mesta (Kenaf)*	*Sunn hemp*	*Ramie*	*Cotton*
Holo Cellulose	80.8	82-85	83.5	85.1	81.7	94.3
α-cellulose	64.1	58-63	60.0	78.3	68.6	94.0
Hemi cellulose	16.7	21-24	23.5	6.8	13.1	0.3
Lignin	2.0	12014	10.1	4.0	0.6	-
Pectin	1.8	0.2-0.5	-	-	1.9	0.9
Fax and wax	1.5	0.4-0.8	0.6	0.5	0.3	0.6
Water soluble extract	3.9	-	-	-	5.5	-
Ash	1.1	0.5-0.8	0.7	0.3	1.1	1.2
Organic Acid	-	-	-	-	-	0.8

TABLE II. PROPERTIES OF JUTE FIBRE IN CONTRAST WITH MAN-MADE FIBRE

Properties	**Fibres**		
	Jute	*Polyester*	*Polypropylene*
Specific gravity	1.48	1.38	0.91
Tenacity, g/d	3 to 5	2 to 9.2	2.5 to 5.5
Breaking Elongation, %	0.8 to 2	7 to 37	17
Elastic recovery, %	75 to 85	57 to 99	75 to 95
Moisture regain, At 65% R.H. and 27^0C.	12.5 to 13.8	0.4	0.01
Effect of heat	It does not melt. Up to 180^0C there is no major wt. loss and tenacity loss. However hemi cellulose degrades around 293^0C and other constituents at higher temperature.	Sticks at 180^0C and Melts at $230^0 – 240^0$C	Softens at 143^0 – 154^0C, melts at 160^0C & decomposes at 288^0C
Effect of acid /alkalis	Good resistant to dilute organic and mineral acids at room temperature but degrades in conc. mineral acids. Affected by hot alkali.	Good resistance at room temperature disintegrates in conc. hot alkali. Excellent resistance to acids.	Excellent resistance to conc. acid and alkalis.
Effect of bleaches & solvents	Resistant to H_2O_2 bleaching conditions. Excellent resistant to organic solvents. However, affected by strong oxidizing agents.	Excellent resistance to bleaches & oxidizing agents.	Resistance to bleaches & solvents. Chlorinated Hydrocarbon cause swelling & dissolves at 160^0C and higher.

V. APPLICATIONS OF JUTE GEOTEXTILES (JGT)

Jute Geotextiles (JGT) have been tried successfully in slope management, erosion control and soil conservation, stabilization of earthen embankment, protection of river and canal bank, strengthening of sub-grade of road pavement and railway track, consolidation of soft soil etc.. Understandably design approach has to be application-specific. Natural geotextiles may be used in conjunction with vegetation in case of erosion control of exposed soil. Bio-engineering measure to control erosion is a much preferred option all over the world for environmental reasons at present. JGT fits in with this trend. Elaborate studies have been done in the developed countries with man-made geotextiles compared to studies on JGT. Standardization of applications along with finalization of specifications of the suitable JGT types is the next step for which necessary initiatives have been taken. What is critical is to evolve design methodologies for different applications with JGT. This is an empirical exercise based on data generated from fields and their corroboration in laboratory. An international project on JGT covering India and Bangladesh sponsored by the Common Fund for Commodities (CFC), Amsterdam, a financial institution of the United Nations, with support from the Governments of the two countries is on way. The project aims at identifying potentially important JGT for erosion control and construction of low volume roads is in progress. Notably more than 150 field applications conducted so far in India with JGT for addressing soil-related problems encountered in road construction, railway track settlement control, control of river bank erosion, stabilization of slope, including hill slope, have proved effective establishing the efficacy of the product. Quite a few field applications have been done in some of the European countries & the USA as well. Bangladesh has obviously been using JGT for soil erosion control and stabilization.

VI. DURABILITY OF NATURAL GEOTEXTILES (JGT)

Durability of natural geosynthetics depends on a number of factors. The type and strength of fibres, soil composition and its physical characteristics, duration and extent of their contact with water are principal determinants in respect of their durability. Environmental factors like atmospheric relative humidity, temperature and the nature and duration of atmospheric exposure also influence durability and strength of geosynthetics (8). In fact, mechanism of degradation of natural geosynthetics is complex. JGT is seen to degrade faster in an acidic ambience with pH value less than 5.2. With pH value higher than 7, degradation of JGT is seen to be rather slow and depends on the linear density of yarns (higher linear density is more susceptible to quicker degradation). On top of it, microbial decomposition of natural geosynthetics is an area of concern. It has been observed that bacteria and fungi with the abetment of favourable ranges in moisture content and temperature hasten degradation of JGT.

The situation therefore warrants treatment with a coating of rot-resistant natural additive. Bio-degradability of natural geotextiles however is not a technical disadvantage as is commonly perceived. Long durability of geotextiles has proved to be an over-rated requirement as corroborated by a good number of field trials. Soil consolidation is optimized by gradual riddance of pore water from the soil due to filtration function of the geotextiles leading to development of effective stress within it. All types of geotextiles, natural and man-made, need to retain tensile strength and their dimensional features for two to three years usually to optimize soil consolidation. Long durability of geotextiles is thus not a technical necessity as all geotextiles act as change-agents to the soil in or on which they are applied.

There have been significant findings also in this regard which can be summarized as loss of strength of JGT after a year which is not a technical disadvantage as by that time JGT provides a self-sustaining sub-grade for most of the soils (Ramaswamy & Aziz-1989), the gain in strength of sub-grade compensates the loss of strength of JGT within the same time-frame (ibid & report of Jadavpur University 2005) and dependence of soil on JGT for stability decreases with the passage of time (9).

VII. Eco-compatibility of Jute Geotextiles (JGT)

Natural fibres are supposed to be eco-compatible by nature from cradle-to-grave. Eco-concordance of retting methods is sometimes questioned. To avoid retting in water as is done in case of Jute, mechanical de-cortification manually or by simple mechanical appliances without water is being tried by some countries such as China. To establish eco-compatibility of natural fibres, Life Cycle Assessment (LCA) study on Jute and important Jute products entrusted to Price Waterhouse Coopers Ltd by national Jute Board reveals that the most significant impact on the Jute life cycle is carbon sequestration by green Jute plants in the agricultural stage. Approximately 4.88 tons of carbon dioxide get sequestered per ton of raw Jute fibre production (10). Jute plantation acts as a sink for carbon. The carbon dioxide emission from Jute is carbon-neutral in nature since the product is from plant-source and can be considered as a bio-mass.

Green House Gas (GHG) emissions from Jute are negative on account of large carbon sequestration in Phase I. All man-made geosynthetics exhibit positive GHG emissions. Air-acidification of Jute & JGT is also far lower when compared to other man-made alternatives (11).

During the 100 days of Jute growing period, 1 Hectare of Jute plant can absorb about 15 metric ton of carbon dioxide from atmosphere and liberate about 11 metric ton of oxygen, the life supporting agent. Studies reveal that carbon dioxide assimilation rate of Jute is several times higher than that of trees (Inagaki, 2000; IJSG 2003). The main use of Jute sticks (a retting output) is as fuel apart from other household uses. Yield of Jute sticks is 2.5 times the fibre by weight (12). Taking overall production of raw Jute / Mesta fibre at 2.7 million tons (in India and Bangladesh), the total output of Jute sticks comes to 6.75 million tons. Considering the other household use at 25 % level, Jute sticks annually saves 5.06 million tons of forest wood and bamboo in these two countries and help in preserving ecological balance. Leaves which are left in the field are good manures and increase the fertility of land. Apart from this, Jute cultivation creates a large direct employment to the farmers, industrial workers and indirect employment to workers associated with ancillary industries.

In view of the 'carbon foot print reduction' concept in construction to ensure marketing eco-friendly products, JGT should attract greater global acceptability.

VIII. Overlooked Environmental Applications with Jute and other Natural Geotextiles

There could be more environmental applications with JGT & coir geotextiles. The overlooked areas are - watershed management, stabilization of mine spoils and overburden dumps, especially in open cast mines, management of pulverized fly ash (PFA) heaps and municipal solid waste (MSW). Only about 11% of the fly ash produced is effectively utilized and the rest are heaped in open lands within the stations. Fly-ash dusts, conveyed by winds, are menace to health. The same may be said about disposal of MSW. Jute hessian has been in use in the overseas for covering up the waste dumps daily (e.g. Brazil). Low cost non-woven JGT can curb spread of pollution caused by accumulated foul gases, liquid pollutants and light waste matter of the refuse heaps. Efficacy of JGT in fostering vegetation in arid and semi-arid zones is well established. Watershed management though critical is still a neglected sector in India where JGT can play a significant role.

IX. Conclusion

With increasing emphasis on using natural ingredients in engineering and other sectors for reduction of carbon foot-print and thrust on adopting bio-engineering measures to tackle soil-related problems in engineering, there is need for continuing research on improvement of fibre-quality It is also felt expedient to organize awareness courses for civil engineers (who are the main end-users of geosynthetics) on Jute

Geotextiles (JGT). Regular courses on Geosynthetics—both natural and man-made-- should be introduced in Engineering Institutes.

Standardization is critical to promote any innovative engineering material. One BI Standard on application of JGT in slopes has already been published (IS: 14986:2007). Two other BI Standards are under print (rural road construction & river bank erosion control). Indian Roads Congress has recently released a document on JGT (State-of-the-art Report on use of Jute Geotextiles in road construction & prevention of soil erosion/landslides). Railway Ministry has started using JGT on unstable formations after successful trials in some distressed sections Burdwan-Howrah Chord Line, West Bengal, India (based on a design concept of the first author presented in Indian Geotechnical Conference at IIT Mumbai in 2000). All these are pointers that JGT is fast catching up both within and outside India. Survival of Jute industry, perhaps the oldest surviving agro-industry in the world, largely depends on acceptance of the product as Jute is fast losing its monopoly in the sack-market.

LCA study of all available & potent natural fibres from 'cradle to grave' should be taken up and a comparative evaluation made including different man-made fibres. Carbon foot print reduction is being advocated globally for all types of construction materials. Continuing R & D on natural fibre-based geotextiles should be carried out and their technical limitations obviated by improving fibre- & fabric- quality. There is a huge need for evolving JGT-specific design methodology & global accreditation of the products with their applications. Besides, JGT deserves special encouragement from the central & state governments and decision-makers for its ensured use especially in the public sector in the greater interest of national economy and for environmental reasons.

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