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Jute Geotextile – A Potential Step to reduce Carbon Foot Print in Civil Engineering Construction

Prof. Swapan Kumar Ghosh[1], Satyaranjan Bairagi2, Murari Mohan Mondal[3] and Rajib Bhattacharyya[4]

[1] Department of Jute and Fibre Technology, University of Calcutta, Kolkata, West Bengal, India

[2] Department of Jute and Fibre Technology, University of Calcutta, Kolkata, West Bengal, India

[3] Department of Jute and Fibre Technology, University of Calcutta, Kolkata, West Bengal, India

[4]Department of Jute and Fibre Technology, University of Calcutta, Kolkata, West Bengal, India

Abstract

Reduction of carbon foot print in constructions is currently attracting global attention warranting innovations in construction technology with stress on eco-congruity. The relentless use of by-products of fossil fuel and mining of stones in road construction has led to gradual shift from conventional materials in road construction to innovative less polluting construction ingredients. Natural fibres are gradually emerging as essential ingredients of various types of Geotextiles. Development of Jute Geotextiles (JGT) 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 meeting most of the technical requirements needed for the major geo-technical applications. This paper delineates physical characteristics of Jute fibre and some of the innovative R & D exercises on JGT executed so far in connection with carbon foot print reduction in civil engineering construction.

Keywords: *Carbon foot print, eco-congruity, geo-technical applications, Jute Geotextiles (JGT).*

1. 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). The use of Geotextile produced by using manmade fibres is non- biodegradable and thus causes severe pollution to the environment due to disposal problem. Moreover during manufacturing of those manmade fibres high energy is consumed leading to discharge of huge amount of carbon dioxide in the air jeopardizing severe threats to environment. Now, it is a well established fact that the increase in carbon dioxide in air is one of the main causes of global warming ready to ruin the human civilization. Therefore, as an inhabitant of this world it is our prime duty to protect our environment and thereby our future generation. One of the most promising and effective ways of mitigating the carbon foot print generation is by replacing manmade fibres with agro-renewable natural fibres. Making of geosynthetics from natural fibres such as Jute and 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.

2. 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 porometric 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.

2.1 Jute Geotextiles (JGT) vis-a-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 of subgrade. 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. Those 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 for which natural Geotextiles are gradually being preferred in less critical areas globally.

2.2 Specialities of Jute

Jute fibres possess good pliancy and render a high degree of flexibility and fineness to fabric construction. 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 and 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) and transmissivity (transmission of water along the fabric) which are comparable to man-made geotextiles. Puncture strength and bursting strength of Jute Geotextiles are also close to man-made geosynthetics. Besides, JGT has a distinct environmental edge over its manmade counterpart.

2.3 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. At present Bio-engineering measure to control erosion is a much preferred option all over the world for environmental reasons like biodegradability, echo compatibility and improvement of soil fertility and texture. 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 and the USA as well. Bangladesh has

obviously been using JGT for soil erosion control and stabilization.

2.4 Suitability of JGT as Geosynthetics in Road Construction

The role of geosynthetics is essentially confined to facilitate consolidation of soil through concurrent functions of separation, filtration and drainage alongwith its capability to withstand stresses induced at the time of installation and as a result of membrane effect in roads. Jute Geotextiles (JGT) can match the performance of its man-made counterpart atleast for one season cycle without any extraneous treatment applied to prolong its durability. The relevant question in the context therefore is the time taken by soil to consolidate with the aid of geosynthetics.

The significant observation in respect of JGT is that the CBR value of sub-grades gets increased in all cases by atleast 1.5 times the control value. This means a pavement can be constructed taking design CBR value as 1.5 times the field CBR value of the sub-grade. The reduction in pavement thickness as a result counterpoises the cost of JGT in most of the cases signifying the use of JGT does not entail any increased cost for the construction.

2.5 Eco-Compatibility of Jute Geotextiles

Natural fibres are supposed to be eco-compatible by nature from cradle-to-grave. Eco-concordance of retting method 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 (NJB), MoT, and GoI 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 and 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 and in this context JGT should attract greater global concern and acceptability.

2.6 Overlooked Environmental Applications with Jute and other Natural Geotextiles

There could be more environmental applications with JGT and 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 vegetative growth, de weeding and canopy of land 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 momentous role.

2.7 Economical and Environmental aspects of applications of Jute Geotextile (JGT)

Use of geotextile enhances the CBR value by 1.5 – 3 time over the control value of subgrade (13). This enhancement of CBR value is advantages because reduction of pavement thickness using JGT compared to the pavement thickness without JGT may be done for getting same performance of the road. The reduction of pavement thickness will directly reduce the cost of road construction as well as reduction in consumption of the raw material for construction of the road. This lower consumption of raw material will lead to conservation of raw materials thereby minimizing the environmental impacts for natural resource extraction activities as well as ecological balance i.e. carbon emission during production. Apart from that, as the reduction of consumption of natural resources will reduce the transportation of raw material thereby saving in the diesel consumption and reduction in carbon emission in transportation.

River bank erosion is a regular and common phenomenon creating immense problem to the Government for the Protection of the river bank. Conventional granular filters are used to overcome river bank erosion. But use of JGT as a remedial measure to protect river bank has been established. Replacement of conventional inverted filter with JGT will conserve sufficient amount of materials, time and money. Boulder are placed over JGT to avoid direct exposure to sunlight and water as well as to dissipate the thrust of wave actions. It has been found that use of JGT in river bank protection (13) work is economical as there will be reduction in initial construction cost as 125 mm thick conventional filter will be replaced by JGT. This reduction of 125 mm thick filler thickness will directly reduce the transportation of granular filter layer to the site. As explained in road construction, reduction in consumption of natural resources will reduce the carbon emission by saving the diesel for transportation.

In hill slope management synthetic geotextile as well as jute geotextile (13) have been potentially used to minimize surficial run off transport detached soil particles caused due to direct impact of rain drops and strong winds. Considering the market price of the synthetic geotextile and jute geotextile, it has been observed that there will be a huge reduction in the cost of JGT compared to manmade geotextile. Jute fibres can absorb water about 5 times of its dry weight. JGT attenuates extremes of temperature, acts as mulch after degradation and create congenial micro climate ensuring quick growth of dense vegetation. Finally root system of vegetation ensures soil retention and also provide sustainable solution to the problems of erosion. JGT, a natural product, fosters vegetation growth and paves a way for bio engineering measure to soil erosional problem.

3. Conclusions

Increasing emphasis on using natural ingredients in engineering and other sectors for reduction of carbon foot-print as well as thrust on adopting technically suitable JGT make it a potential material worth trying in roads. In view of the fact that its application over the sub-grade enhances CBR of the sub-grade and can act as an excellent drainage medium, pavements can be designed with lesser thickness than is necessary for conventional construction. Reduced thickness of pavements will diminish the consumption of fossil fuels and natural resources used in road construction and curb the Carbon Foot Print as a result. 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 (based on a design concept 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 and potent natural fibres from ‘cradle to grave’ should be taken up and a comparative evaluation may be 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 and 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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