DEVELOPMENT AND APPLICATION OF POTENTIALLY IMPORTANT JUTE GEO-TEXTILES (CFC/IJSG/21)

FINALTECHNICAL REPORT

2016

This report is the outcome of project on Development and Application of Potentially Important Jute Geo-textiles (CFC/IJSG/21)funded by the Common Fund for Commodities and the OPEC Fund for International Development

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Disclaimer:

National Jute Board (NJB) was awarded a project by the Common Fund for Commodities (CFC) on Development and Application of Potentially Important Jute Geotextiles - IJSG/CFC/21) as Project Implementation Agency (PEA) while National Jute Board (NJB) and Jute Diversification Promotion Centre (JDPC),Bangladesh were the two collaborating institution (CI) for India and Bangladesh respectively

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ABBREVIATIONS AND ACRONYMS:

AOS Apparent Opening Size

CFC Common Fund for Commodities

ESAL Equivalent Standard Axle Load

IIEST Indian Institute of Engineering Science and Technology

IJIRA Indian Jute Industries' Research Association

IJT Institute of Jute Technology

IJSG International Jute Study Group

JDPC Jute Diversification Promotion Center

JGT Jute Geo-textiles

JMDC Jute Manufacturers Development Council

NJB National Jute Board

NSRI National Soil Research Institute

OFID OPEC Fund for International Development

OW Open Weave

PEA Project Executing Agency

PMGSY Pradhan Mantri Gram SadakYojana

PWC PricewaterhouseCoopers

SoR Schedule of Rates

EXECUTIVE SUMMARY

A project on development and Application of Potentially Important jute Geotextiles (CFC/IJSG/21) was initiated in India and Bangladesh from August 2009 to December 2014 which was extended till June 2016.

The rationale of implementing the project was that there is a need and potential to develop a new product in jute sector as a part of strategy to retain and expand its overall market. Jute Geotextiles have been identified as an opportunity for the development and introduction of a technically and financially competitive product, which eventually could claim a substantive market share in a growing market, thus far dominated by synthetic materials. It was envisaged that socio-economic condition of people, involved in jute sectors in developing countries by increasing the consumption and market share of jute globally, on a sustainable basis, through the development and expansion of jute geotextile market.

The project was estimated with a total cost of USD 3,962,826 of which USD 2,045,000 was in the form of grant from CFC and the balance were contributions by Government of India, Govt. of Bangladesh and other private partners. The project was supervised by the International Jute Study Group (IJSG) and thereafter National Jute Board acted as supervisory body after its closure.

The objectives of the project were to :

a) Determine and demonstrate the effectiveness of jute geotextiles (JGT) in two pre-identified promising applications (soil erosion control and rural road construction)
b) Standardization of selected jute geotextiles
c) Market need assessment and environmental impact assessment

The five major components of the project were :

a) Component 1: Market needs assessment and supply chain analysis
b) Component 2: identification of Potentially Important Jute Geotextiles based on performance Evaluation
c) Component 3: Manufacture of the Identified or selected Potentially Important Jute geotextiles and its Standardization
d) Component 4: Documentation and Dissemination
e) Component 5: Project Management and reporting

The project was implemented in 13 field trials for rural roads totalling 199762 Sq. Meter (57.862km length), 11 field trials for river bank protection works totalling length of 8715m and 8 field trials for hill slope management works in different districts of both the countries. The field applications were monitored and implemented by the government agencies, PEA and FA's.

Benefits derived from the project were:

a) Satisfactory performance of JGT in the fields is an encouraging factor for end-users and decision makers.
b) Improved sharing of technology between researchers, engineers, marketers, companies and jute growers.
c) Able to assess the potential of JGT market in India and Bangladesh
d) Understand the technical requirements of end-users like supply in time, quality assurance, installation guide dance, etc.
e) Documentation of standards, inclusion in schedule of rates, technical papers for increase in demand of JGT
f) Poverty alleviation

The report is the outcome of project on Development and Application of Potentially Important Jute Geo-textiles (CFC/IJSG/21) funded by the Common Fund for Commodities and the OPEC Fund for International Development Mission. Both Bangladesh and India have successfully implemented the project activities in three identified areas like, erosion control of hill slope & river bank and road construction and came out with encouraging results.

Under the project two types of woven JGT and three types of open weave potentially important jute geotextiles (JGT) were designed & developed in a such a simplified manner that any jute mill can manufacture all the varieties of JGT

by utilizing their existing machinery. The products were tested as per standard testing methods and the results could easily meet the technical requirements and set parameters for using in erosion control and road construction works. To enhance the life of JGT its treatment with eco- friendly additive was also been developed for use in river bank erosion control which were tried with success in both the countries.

The fabrics developed were standardized and the specifications have been published by the standard making authorities of both the countries (Bangladesh- BDS 1909:2016 and India- IS 14715, Part I & II: 2016). Attempts would also be taken to make its international standards in future. Products have also been included as item of work in the Schedule of Rates (SoR) by different Govt. departments in both the countries. Design methodology with economic advantagesand application guide lines have been prepared. It was also estimated that there will be no dearth in manufacture & supply of JGTs developed under the project by the jute mills in both the countries.

From the results of the field trials it has been established in both the countries that Open weave JGT (500-700 gsm) is capableto controlerosion of hill slope effectively, 20 kN/m tensile strength woven JGT of 627 gsm is quite effective for river bank erosion control while 25 kN/m tensile strength woven JGT could strengthen the road sub-grade remarkably by increasing CBR% more than double. Demand of JGT from the end users has been noticed to be increasing which will ultimately help the jute mills workers and farmers for their livelihood and alleviate poverty level.PwC conducted an extensive market survey to assess the overall market and the projected demand of JGT, demand of JGT is likely to reach 1300 million sq. m. By 2020.There will be no dearth in manufacture & supply of JGTs developed under the project by the jute mills in both the countries.

So long India has organised / participated in 104 awareness programme on JGT and Bangladesh has done 26 such programmes. More than 40 technical documents / literatures on JGT has been published and circulated among the concerned engineers / decision makers.

The findings of the project have been disseminated through seminar, workshop, exhibition, awareness programmes etc. Dissemination on interim findings has already been done through 2 National Workshops in 2013 at Kolkata and 2014 at Dhaka. Results achieved at the end of 6th year (PY 6) of the project have also been disseminated through 2 more National Workshops held in May, 2016 at Kolkata and in June, 2016 at Dhaka. After successful completion of the two National Workshops, one in Kolkata and another in Dhaka, the International Seminar was held to disseminate the outcome of the project and to exchange views to ultimately draw inference/ conclusion and make recommendation out of the project activities. Dignitaries from all the project partners / contributors, end users, geotechnical consultants, engineers, scientists, academicians, manufacturers, from national internal levels actively participated in the International Seminar.

However, further research is felt necessary to find out the actual mechanism of improving the soil characteristics after using JGT in spite of its biodegradable nature. R & D work should also be undertaken to use JGT in number of new areas in civil and environmental engineering.

It is felt necessary that the ongoing awareness programme to disseminate results and findings of the study under the project among the geotechnical engineers should be continued in massive way all over the world to achieve the goal for popularizing JGT.

1. INTRODUCTION

The project commenced in January, 2010 and ended in June 2016. Jute, an one time major foreign exchange earner for India , Bangladesh and the sub-continents as well as the provider of livelihood of millions of people gradually lost its market mainly due to inroads of cheaper variety of synthetic materials particularly in packaging sector during mid ‘70s. For the survival of this century old industry scientists / engineers had developed diversified jute products like jute geotextiles (JGT) in mid ‘80s. Since then the products are being in use with success sporadically by the civil engineers. In spite of its unique features JGT could not be as popular as it deserves to be. The reasons might have been the lack of awareness, hassles in manufacture of specific type of JGT, absence of authentic adequate data to establish its efficacy, non-availability of standards etc.

The project aimed to lead to the commercial acceptability of potentially important JGT suitable for use in two identified end-uses namely, soil erosion control of hill slope & river bank and rural road construction in Bangladesh

and India. Results achievedare expected to lend themselves to be extrapolated to conditions in other (potential market) countries. The project included development of material specifications, field application / installation protocols and design methodologies for these applications in compliance with requirements and standards set by public and private sector users. Market needs assessments and compliance studies are included in the project. The outcome of this project is expected to lead to substantial expansion of the market uptake of jute geo-textiles for use in the fields of soil erosion control and rural road construction in commercially competitive markets (both domestic or regional and international).

The project is strongly supported by the ICB concerned. Additional benefit achieved out of this project is to use lower grade fibres for manufacture of JGT, thus adding a higher value to a lower value material and higher grade fibres can be used for value added Diversified Jute Products which will be beneficial to jute farmers economically.The derived increased annual demand for jute is expected to be ultimately 265,000 tons or more.

In view of larger acceptability of the products by the civil engineers globally and in particular in India and Bangladeshdifferent types of woven and open weave jute geotextiles of potentially important have been developed under the project and were applied in the field both in India and Bangladesh.Total 26 (16 in India and 10 in Bangladesh) numbers of applications were carried out in three areas like, i) Erosion Control of Hill Slope, ii) Erosion control of River Bank and iii) Rural Road Construction.To evaluate their actual performance extensive monitoring works were undertaken and the findings of the results so achieved were highly encouraging. The findings of the study have been documented and disseminated among the civil and environmental engineers.

2. PROJECT OBJECTIVES, IMPLEMENTATIONS AND COMPONENT

2.1 Objective and Expected Outputs

The objective of the project was to identify / develop potentially important JGTs to determine their effectiveness in two identified application areas like soil erosion control of hill slope & river bank and rural road construction both in Bangladesh and India by some field trials followed by monitoring. At that time adequate authentic documents on laboratory tests as well as field trials were not yet available. In view of commercial acceptability of JGT it was necessitated to develop the products, to evaluate their performance through field applications, prepare the standard specifications and installation guidelines and design methodologies in compliance with requirements and standards set by public and private sector users.

After fulfilment of objective the expected output is that this project will lead to substantial expansion of the market uptake of JGT for use in the fields of soil erosion control in hill slope & river bank and rural road construction commercially competitive markets both Indian, Bangladesh and international market. Previous studies and applications so far undertaken were not comprehensive enough for large scale acceptability and adoption. The applications, however, did not focus on design and manufacture of application-specific and function-orientated varieties of JGTs. Assuming the success of the project, the derived increased annual demand for jute is expected to 265,000 tons or more.

Once the JGT is accepted in both countries and in the international market, it is expected that use of JGT will increase significantly resulting into extensive benefits to jute cultivators, jute mills work force, the jute industry as a whole and to the end user organizations involved in road construction, river bank erosion control, hill slope stabilization works.

2.2 Project Implementation

In order to implement the project successfully India and Bangladesh as CI engaged the following Facilitating Agencies (FA) with defined tasks :

India - PricewaterhouseCoopers (PwC), Bengal Engineering and Science University- Shibpur (BESUS), Indian Jute Industries' Research Association (IJIRA), Institute of Jute Technology) IJT and additionally Central Soil and Water Conservation Research and Training Institute (CSWCRTI) now Indian Institute of Soil & Water Conservation (IISWC) at Dehra Dun

Bangladesh – Bangladesh University of Engineering & Technology (BUET), Bangladesh Jute Research Institution (BJRI) and additionally Soil Resources Development Institute (SRDI), Department of Road & Highways (R&H), Water Development Board, Public Works Department etc.

PEA also engaged National Soil Research Institute (NSRI) of Canfield University – UK to study Environment Impact Assessment (EIA). Jute mills in both the countries were also the significant contributors in the project. Government of both the countries supported and helped implementing the project.

Responsibilities of GoI&GoB were to identify sites for rural road construction as well as erosion control in river banks and hill slopes required for technical evaluation of JGT under various climatic and geotechnical conditions, to bear the costs of constructions of such projects excepting the cost of JGT, to include JGT in consultation with IIEST in India & BUET in Bangladesh in the identified projects for technical evaluation of JGT, to assist the said institutes in India & Bangladesh by providing pre-work information on the site conditions related to the two specific applications and collecting post-work technical information, to make provisions of the costs for technical evaluation of JGT under various environmental conditions in the relevant estimates.

2.3 Market survey

PwC conducted an extensive market survey to assess the overall market and the projected demand of JGT. Results indicate that Geotextiles demand was expected to grow as per a Compound Annual Growth Rate(CAGR) of nearly 10% from 870 million square metres in2016 to around 1300 million square metres in 2020.

India plans, in its Rural Road Vision year 2025 to construct about 1,58,000 km of new roads and upgrade 84,181 km of existing roads. Moreover, the Government of India approved Rs 8,000 crore for Flood Management Programme to be implemented across states to assist states in river management, flood control and anti-erosion works. These two sectors are expected to use JGT in bulk quantity. The Indian domestic demand is projected to grow on an average at 8.5% CAGR by 2020.

The Bangladesh government aims to connect all rural areas with national road network over the next five years investing about Tk. 14,876 crore (US$ 1836million) in developing the transport system. Bangladesh, of late has been committing investments and providing policy impetuses in building domestic JGT capacities corresponding to yearly demand of19.3 million sqm.

The international market for natural geotextile put together with demand from India& Bangladesh was estimated to reach 870 million sq m in the year 2016, whereas the total potential of the entire Geotextile (natural and synthetic) opportunity would be about 4880 million sq m in the year 2016.

The survey indicated that if JGT is to meet acceptability both in national and international markets, there is an immediate need for standardization. In this regard, the Indian Roads Congress was approached for accepting JGT as a road-improving product and the Congress has indeed permitted use of Jute Geotextiles as an innovative construction material. The National level Standard making body of both India and Bangladesh have already published standards on JGTs.

It has been revealed through interactions with the end users that the 26 field trials conducted in the specified areas have reestablished the efficacy of JGT as an eco- friendly and cost efficient construction material. Although it is difficult to exactly quantify the increased demand of JGT but it can be clearly stated that off-take of jute as geotextiles will help in poverty alleviation in jute-growing areas and in improving the living conditions of farmers and workers.

2.4 Design and Development of Potentially Important JGT

IJIRA envisaged on the basis of past successful observations on field studies of more than 60 roads in India as well as simulation study (Sahu R B et.al., Behaviour of Geo jute Reinforced Soil Bed Under Repetitive Loading- A Model Study, Proc ICGGE-2004, IIT Mumbai,Dec,2004) with 760 gsm JGT of 20 kN/m. On that basis, new fabrics were designed and developed of lower weight than 760 gsm having minimum tensile strength of 20kN/m to 25 kN/m for river bank erosion works and rural roads (CFGG French Committee of Geotextiles and Geomembranes, 1986, Geotextiles Manual) respectively with a porometric range of 150µ to 400µ as most type of soils have similar range of grain size distribution. Designed new JGTs were developed keeping in mind to economize cost of fabric without

impairing the two main criteria of attaining tensile strength and porometry of fabric. Also three types of Open Weave (OW) JGT i.e. 500 gsm, 600 gsm and 700 gsm for erosion control of hill slope was designed and developed as shown in Table1 in Annexure1. Weight of the fabric so developed was calculated adopting the standard formula. Emphasis was also given to simplify manufacturing methods so that any jute mill can manufacture the product utilising the existing machinery with economic advantage.
The Institute of Jute & Technology (IJT, University of Kolkata), tested all the fabrics thus developed at their well-equipped NABL accredited geotextile testing laboratory and the parameters so obtained were found to meet the technical requirements.

3. Engagement of Facilitating Agencies (FA) for Project implementation

Tasks of the Facilitating Agencies (FA)were defined as per requirement and pertinent contracts for the involvement were based on ToRs prepared by the PEA, within the framework of its own responsibility vis-a-vis the Common Fund for Commodities (CFC) and International Jute Study Group (IJSG). An overview of the FAs engaged and their tasks is presented below.

I. PricewaterhouseCoopers (PwC)

The international consultant PricewaterhouseCoopers (PwC) was involved in this project with the specific responsibility to undertake strategic planning for marketing the potentially important JGT for the two specified applications in Europe. Tasks were to assess the market needs in the sector of soil erosion control and temporary low volume roads in Europe, to conduct supply chain analysis and market research on acceptability of JGT in low volume road construction and soil erosion control and to chalk out an objective programme for securing globally acceptable certification of the Potentially Important JGT for the two specific applications on the basis of the findings of the project.

II. Bengal Engineering & Science University, Shibpur (BESUS),presently Indian Institute of Engineering Science and Technology (IIEST), India

The responsibility of the Indian Institute of Engineering Science and Technology (IIEST) in,Shibpurwas the Technical Evaluation of Performance of Jute Geo-textiles in Soil Erosion Control and Rural Road Pavement Construction in India in association with Institute of Jute technology. Following parameters were considered to evaluate the performance of JGT : a) Material characterization, b) Testing of JGT & durability of JGT, c) Assessment of soil loss and determination of hydraulic conductivity of soil after application of JGT under different influencing parameters for soil erosion control, d) identifying the most suitable types of JGT through simulation studies, e)Assessment of pavement performance in relation to time vis-a-vis durability of JGT, f) Based on field studies on rural road construction and identifying the most suitable JGT-type for the purpose through laboratory simulation studies, g) Standardization of the engineered fabrics.

III. Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh

The responsibility of the Bangladesh University of Engineering and Technology (BUET) was the testing and product evaluation of jute geotextiles (both in laboratory and in the fields) in Bangladesh. The responsibility includes the Technical Evaluation of Performance of Jute Geo-textiles in Soil Erosion Control and Rural Road Pavement Construction as was supposed to be done in India by IIEST. Standardization of the products through appropriate body in Bangladesh was also the task of BUET.

IV. Indian Jute Industries' Research Association (IJIRA), Kolkata, India

The Indian Jute Industries Research Association (IJIRA) is a well reputed research institute on jute that has been doing extensive research, development and application of JGT since 1985. Wide varieties of JGTs like woven, non woven and open weave were developed by IJIRA and have been applied successfully in the field. Of late IJIRA has been declared by Govt. of India as Centre of Excellence (CoE) on JGT. For this project, the responsibility of IJIRA was to provide requisite inputs related to the fabric engineering part of the development of JGT to IJT & BJRI for the two specific applications in accordance with the design specifications and to provide installation guidance for field application of JGT in erosion control and rural road construction in India.

V. Institute of Jute Technology (IJT), Kolkata, India

Responsibility of IJT was to collect random samples from the entrusted mills in India, to test them in its laboratory and characterize materials, to advise mills in India & Bangladesh on production & quality control, to design appropriate fabrics for the two specific applications and advise the mills on quality control and production of JGT on the basis of inputs provided by IIEST, BUET, IJIRA and BJRI. Furthermore, IJT was to share with IIEST Shibpur in India & BUET Dhaka in Bangladesh the results of tests and associate with the said institutions in finalization of specifications for potentially important JGT for the two specific applications.

VI. BangladeshJute Research Institute (BJRI), Dhaka, Bangladesh

The responsibility of the Bangladesh Jute Research Institute (BJRI) was to share the requisite inputs related to fabric engineering part of the development of JGT for the specified applications with IJT& IJIRA, to provide the installation guidance for field application of JGT in the areas of erosion control and rural road construction in Bangladesh.

VII. Governments of India (GoI) & Bangladesh (GoB)

The Governments of India and Bangladesh have been associated actively in this project for the overall policy support. The departments of the governments of both countries of India and Bangladesh concerned with road construction, construction of embankment, soil conservation, etc. have contributed to the project in kind, bearing the cost of all civil works associated with activities of soil erosion control and construction of rural road pavement .

Organisations such as the Soil Resources Development Institute (SRDI), Department of Road & Highways (R&H), Water Development Board, Public Works Department of Bangladesh, the Central Soil and Water Conservation Research and Training Institute ,now Indian Institute of Soil & Water Conservation (IISWC) at Dehra Dun (India) and the Central Road Research Institute (CRRI, India)undertook the Technical Product Evaluation component of the programme. This has been done by a) locating suitable field test sites to reflect a range of agro-climatic conditions, b) installing test equipment and monitoring devices, and c) collecting and collating all relevant data.

The responsibilities of GoI&GoB were to offer sites for rural road construction as well as for erosion control in river banks and hill slopes required for technical evaluation of JGT under various climatic and geotechnical conditions, to bear the costs of constructions of such projects excepting the cost of JGT, to include JGT in the identified projects for technical evaluation of JGT, to assist the said institutes in India & Bangladesh by providing pre-work information on the site conditions related to the two specific applications and collecting post-work technical information and to make provisions of the costs for technical evaluation of JGT under various environmental conditions in the relevant estimates.

VIII. Environmental Research Institutes in India & Bangladesh

Well-equipped domestic Environmental Research Institutes in India & Bangladesh specialized in environmental evaluation and impact assessment were engaged to undertake comparative Environment Impact Assessment (EIA) on use of JGT and man-made geo-textiles in rural road construction and soil erosion control in India and Bangladesh. They have given feed-back on field results to NSRI, Cranfield University, UK and/or consultants as necessary with 'cradle to grave' approach.

IX. National Soil Resources Institute (NSRI), Cranfield University, UK

The National Soil Resources Institute (NSRI) was given the responsibility to undertake a comparative EIA with JGT vis-a-vis man-made geo-textiles /other natural geo-textiles for soil erosion control applications. IJIRA was supposed to be in close touch with NSRI in the matter, to conduct appropriate model study simulating all the relevant field parameters and corroborate/collate the results with the field findings, to provide technical inputs for developing potentially important JGT for soil erosion control to conform to International standards.

X. Private Partners in India and Bangladesh

A number of jute mills with proven records of manufacturing JGT were involved in the project for manufacturing a wide variety of JGT to be tested for technical evaluation. Gloster Jute Mill of India and Janata Jute Mill Ltd of

Bangladesh were the principal partners in this project and other mills participated thereafter. Specified quality and quantity of JGTs were manufactured and supplied by the mills at break-even costs for lab tests, simulation and also field trial applications. They extended support to make minor adjustments in the machinery for higher production and improved quality of JGT and to arrange treatment of JGT, if necessary, with specific additives including bitumen.

4. ENVIRONMENTAL IMPACT ASSESSMENT

4.1 Jute field agronomy

Energy is required to undertake jute cultivations, often in the form of animal traction (e.g. oxen) and the plough. Aftersowing, a huge quantity of water is required for growth of jute and fertilisers are also added to aid growth of the plant. Fertilisers are generally sourced organically (Basu et al., 2009), reducing financial and environmental production costs of chemical fertilisers based on finite, non-renewable resources. During jute cultivation, macro and micro nutrients are removed from the soil by plant uptake, making a requirement for fertiliser additions for the next crop. Indeed a gradual depletion of nutrients and soil structural degradation may have collectively contributed to the crop yield declines in the rice–wheat–jute rotation (Manna et al, 2006).Pesticides are also used in jute production (Basu et al., 2009),with disease control in the jute crop chiefly undertaken through crop rotations with rice and other cereals, vegetables, oilseeds and pulses (Islam, 2013). This latter approach has less negative environmental impact than the use of agrochemicals to control pests and diseases. PwC (2006) considers the use of pyrethoidcypermethrion to control pests in jute. However, the half life of the product is only 4.8 days, so “there is almost no chance of the residual remaining on the jute fibre”.
Jute plants do add organic matter back to the soil in the form of leaf-loss estimated to be 15 tonnes of leaves per hectare of jute (International Jute Study Group, 2003). Jute contains 41% carbon (PwC, 2006), and carbon sequestration by green jute plants is the ‘most significant impact in the jute life cycle’. Approximately 4.88 tonnes of CO_2 gets sequestrated per tonne of raw jute fibre production. This is offset by methane emissions from retting ponds, but overall the greenhouse gas emissions become negative as jute plantations act as a sink for carbon (PwC, 2006). Jute adds more biomass (7.79–8.55 t dry matter ha^{-1}) to soil than paddy (1.14–2.93 t dry matter ha^{-1}) (Hossain et al., 1994).

Other documented environmental benefits of jute production include the ability of jute to remove arsenic from soils. This reduces the soil arsenic load as well as the human intake associated with the next edible crop produced from the same field (Majumderet al., 2013).

Figure 1: Jute harvesting and bundling

Jute plants requires weeding and crop thinning practices. This is generally done manually and requires energy. Jute is also harvested and bundled manually in the field (Fig-1). Absence of mechanised system poses a health risk to farmers as a result of long working hours, with approximately 200 – 400 man days required per hectare for jute cultivation (FAO, 1998). In waterlogged fields, workers’ health is also at risk as a result of the length of time spent standing in potentially polluted water (FAO, 1998).

4.2 Jute fibre separation

Current practice dictates that jute stem bundles are immersed for 15-18 days in slow flowing fresh water such as those found in deltaic regions, floodplains, ponds and ditches (Mondal and Kaviraj, 2008; van Dam and Bos, 2004). This requires a large quantity of water with an approximate volume ratio of 1:10 (van Dam and Bos, 2004). Where

possible, the retting process is undertaken in close proximity to the farm thus requiring little energy to transport the harvested jute.

Figure 2 : Jute retting and fibre extraction

Retting has a direct environmental impact on water quality and on the flora and fauna present. During the retting process, jute decomposition releases natural waste products into the surrounding environment. One such waste product is methane, which is released at an estimated rate of 148 mg m^{-2} h^{-1}. This rate has been documented to exceed the emission rates of Indian rice fields (Banik et al., 1993). This equates to approximately 18.8 x 10^{10} g yr^{-1} methane (Banik et al., 1993). Methane contributes to atmospheric greenhouse gases at a potencyof28 times that of CO_2impacting global climate (van Dam and Bos, 2004).Methane gas can also generate a bad odour making for an unpleasant environment surrounding retting sites (Haque et al., 2002). Another potential source of pollution from the retting process is arsenic. This chemical can be absorbed from contaminated soil by jute plants. As they break down, the arsenic can enter the retting waters. In places, this has been found to generate levels of arsenic in water that exceed the safe level prescribed by the World Health Organisation for India and Bangladesh (Majumder et al., 2013), putting the health of local water users at risk.

However, on the positive side, where artificial retting ponds are used, organic residues produced from jute decomposition can be used as green manure to improve soil fertility. This is essential to the sustainability of jute production (Manna et al., 2006).

4.3 Jute fibre processing

Jute fibre is first brought from the farmers to the market and then transported onward to the mill. This requires energy, including transportation fuel, and generates potentially harmful atmospheric emissions. At the mill, jute is softened to improve fibre processing to reduce fibre waste and for the ease of spinning (Dilruba et al., 2010). This is undertaken through the application of an emulsion made up of oil, water and a surfactant (Basu et al., 2009), known as ‘jute batch oil’, JBO. Traditionally, the oil used was typically a costly and non-renewable mineral oil (C_{12} – C_{31} fraction). A large amount of energy was required for its production, with associated emissions during production(Basu et al., 2009). JBO is non biodegradable and hydrocarbon contamination from jute has been traced to the use of JBO in the batching process (PwC, 2006) and uncontrolled use of jute batching oil contributes to a ‘human toxicity’ impact. To combat this problem, vegetable oil like rice bran oil has been developed by IJIRA to replace JBO, a more sustainable practice which has now become very popular in the jute industry.

Remaining environmental impacts come from the machinery used in the spinning and weaving process that mostly affect the factory workers. Most mill operations are mechanised and unless suitable protection measures are in place, workers’ health is at risk as in the case for any factory environment. The processing of jute (especially the carding process) generates a considerable volume of dust. A mill of 100 tonne per day production capacity generates about 4 tonne per day of jute dust (PwC, 2006). If not properly removed / controlled, the inhalation of vegetable fibres can cause occupational lung disease (van Dam and Bos, 2004).

Figure 3 : Processing of JGT

5. APPLICATION OF JGT AT SITES

Potentially Important JGTs developed under the project were appliedin the field both in India and Bangladesh to evaluate their performance. Total 26(16 in India and 10 in Bangladesh) numbers of applications were carried out in three areas like, i) Erosion Control of Hill Slope, ii) Erosion control of River Bank and iii) Rural Road Construction. The theoretical analysis was taken up on four JGT treated rural roads in India using ABAQUS Software by BESUS.16 applications in India comprises 7 roads, 6 rivers and 3 hill slopes while 10 applications in Bangladesh comprises 5 roads, 3 rivers and 2 hill slopes.

5.1 HILL SLOPE PROTECTION

The identified area needs to bedressed, cleaned and the angle of slopeismade as gentle as possible, preferably at an angle of internal friction of soil. Designated OW JGT, generally available in the form of roll is installed on the slope surface by unrolling down from the top. The two ends are anchored in trenches of suitable dimension dug at top and at toe of the slope(Fig-4). Pieces of JGT are laid parallel to each other along the length of the slopewith anoverlapof 10 cm. JGT to be taken to ensure that itgets intimate contact with the slope surface at all points.

Inverted 'U'shaped nail or locally available pegs are used at an regular interval to fix the fabric on to the ground. Grass /Tea / other species are planted on the slope surface through the openings of the O W fabric. Preferred time of installation of JGT for such application is in pre-monsoon period, otherwise occasional watering is recommended for quick growth vegetation.

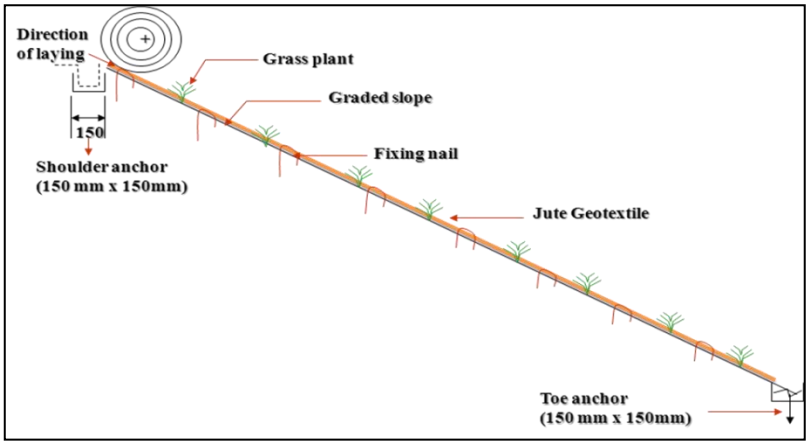

Figure 4: Typical Cross Section of Layout of Hill Slope

5.2.RIVERBANK PROTECTION

Soil particles seldom pass through geotextile pores singly in an endless stream after initial migration of a small proportion of finer soil particles while the coarser ones form arches over the pore openings to restrain other particles from migrating. Further loss of soil can be expected only if two particles positioned side by side can find sufficiently bigger pores of geotextile to pass through. The factors of hairiness and swelling of JGT (which can go up to the extent of 40%) are supposed to restrain most of the soil particles through the fabric pores adopted with the retention

and permeability criteria in view. This concept is consistent with the findings of Elmer who found that even fairly uniform sands can bridge a regular opening of 2-3 times the average particle size i.e d_{50}.

With this in view from literature stated by John (1987), Ingold (1984) and based on our experience in the field we recommend the following porometry for Jute Geotextile (JGT) in relation to the average particle size of bank soil which addresses both the retention and permeability criteria.

If d_{50}> 0.075 mm, AOS (O_{95}) < 600µm
If d_{50}< 0.075 mm, AOS (O_{95}) < 300µm

For Jute Geotextile we can quantify i.e. pore size for river bank application could be of the order of four (4) times d_{50}in view of jute fibre features as indicated above. The modified relation therefore stands as under:

If d_{50}> 0.075 mm, AOS (O_{95}) = 4 d_{50}< AOS < 600 µ
If d_{50}< 0.075 mm, AOS (O_{95}) ≤ 300 µ

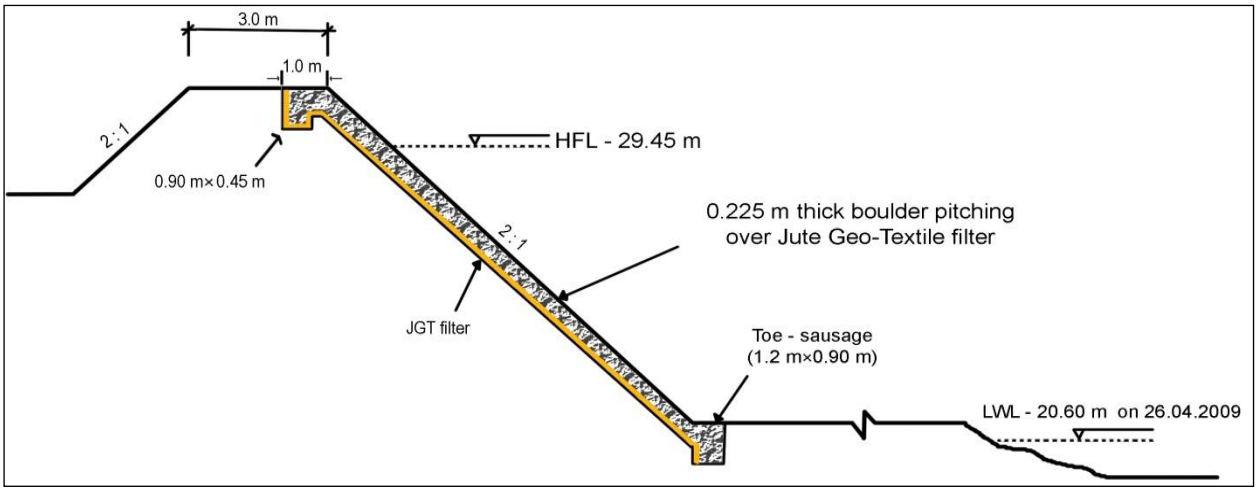

Figure 5: Typical Layout of Riverbank Protection

The bank first to be cut/filled to a stable slope at an angle of internal friction of the bank soil.The surface to be levelled and made free from angular projections, undulation, soil-slurry or mud.Anchoring trench to be excavated at the top of bank slope.JGTis unrolled along the slope from top to down up to the lowest point of the slope (including falling apron)**.** JGT to be adequately embedded in the trench and to be stapled at each corner of the trench. The anchorage trench to be filled with stones for securing and protecting JGT(Fig5).Care to be taken to ensure that JGT does not suffer damage due to puncture, tear and similar operational stresses.The overlap is 100mm. The overlapped portion to be pegged at an interval of 300mm using 6mm wire U-hook/nails.JGT to be taken to ensure that JGT touches the bank slope at all points.

5.3.RURAL ROAD CONSTRUCTION

For design of JGT, tensile strength of JGT has been kept at 25kN/m irrespective of site condition as any greater value of tensile strength is usually not required for low volume roads. The mentioned tensile strength is sufficient to take surcharge load of pavement materials (base and sub-base), installation stresses as well as the dynamic loading conditions imposed on low volume roads with course of time. Another important feature about design of JGT is finalizing its parametric feature which is a factor of grain size distribution of sub-grade soil. It is also been observed in field applications that fulfilment of retention criterion of JGT also concurrently achieves the desired value of

permittivity. Parameters of deciding on the pore-size of JGT from functional stand point are indicated below by Caroll (1981) for man-made wovengeotextiles.If $d_{85} \leq 75\mu$ then $O_{95} \leq 2d_{85}$.

The above equation was modified for JGT due to presence of protruding jute fibres across the pores of fabric when comes in contact with soil and water reduces the actual pore size and swelling properties of fibre/yarns. If $d_{85} \leq 75\mu$ then $O_{95} \leq 2 - 3\ d_{85}$. The particle size distribution of sub-grade soil to determine parametric value of JGT as required. In case of rural road, the width of carriageway is such that would not permit two-way traffic in two lanes. This implies that road will be subjected to both way traffic within its width. Lateral overlapping of 100mm and longitudinal overlapping of 150 mm had been provided at the ends. As mentioned in detailed project report of the road, the effective width of JGT proposed was 4.60 meter. Accordingly, 5 lengths of JGT were laid one after the other laterally depending upon load dispersion direction as shown in figure below providing overlapping of 100cm (**Fig6.2**).

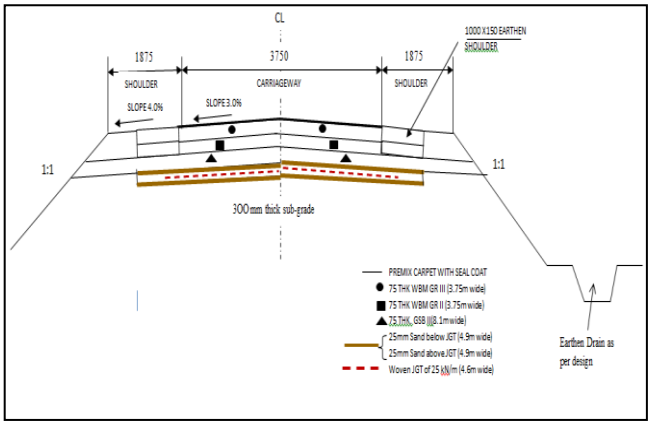

Figure 6.1: Typical Layout of Rural Road

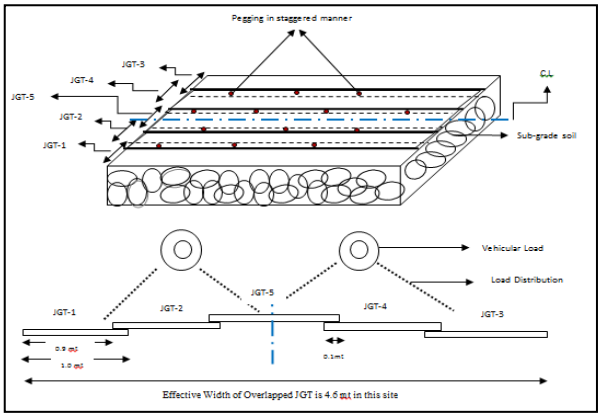

Figure 6.2: Typical Lateral Overlapping of

6. MONITORING AND PERFORMANCE OBSERVATIONS:

6.1. HILL SLOPE PROTECTION

To assess the effects of JGT in hill slope monitoring was conducted at an interval of 6 months. Run-off plots were arranged in field where tea seedlings were planted then runoff and soil loss were monitored using multi-slot devisors.Erosion pegs (wooden) were installed at regular intervals across the treated and untreated areas for recording the depth of soil eroded, if any. It was found that there was no visible erosion taking place in the JGT area and no rills were observed.

The JGT material was found intact even after one year of installation, though degradation in strength took place. The soil and moisture conserved due to presence of JGT resulted in growth of vegetation at places. Soil moisture content was monitored at regular intervals to quantify the effect of different types of JGT on the moisture retaining capacity of the soil. Plant growth parameters of tea were monitored up to two years at every two months interval after planting. Runoff, soil and nutrient losses were monitored for a three years period from 2012 to 2014 and pooled data were analyzed and interpreted. Since the objective of applying JGT is to promote more biomass growth in degraded lands, grass and other herbs grown in between tea plants were removed and biomass production was recorded after oven drying the material**.** Fig 7.1 and Fig 7.2 show the effect of JGT in actual field application.

Figure 7.1: Performance of JGT after Six Months

Figure 7.2: Performance of JGT after One Year

No visible erosion and rills took place in JGT treated area. Soil moisture was retainedand JGT helped growth of vegetation (Fig 7.2). Soil moisture content was monitored at regular intervals to quantify the effect of different types of JGT on moisture retaining capacity of soil. Plant growth parameters of tea were monitored up to two years at every two months interval after planting. Runoff, soil and nutrient losses were monitored for three years from 2012.

6.2.RIVERBANK PROTECTION

The riverbank protection was monitored at a regular interval and collected data to assess the performance of the JGT.The treated bank was found to be stable after one season cycle. No sign of distress / cleavage were observed in the treated zone. Laying of JGT and its effect during three years are shown in **Fig 8.1 (laying),8.2(Soil sample collected at site), 8.3 (condition after 2 yrs)& 8.4 (condition after 3 yrs).**

Figure 8.1: Laying of JGT

Figure. 8.2: Soil sample collected at site

Figure 8.3: condition after 2 year of application

Figure 8.4: condition after 3 year of application

6.3. RURAL ROAD CONSTRUCTION

Regular monitoring has been carried out, both visual observation and instrumental monitoring. Finally assessment has also been done by determination of cumulative Equivalent Single Axle Load (ESAL), was examined and it was observed that traffic volume in the JGT treated roads increased significantly as compared to untreated village roads. It was also observed that CBR% has increased, OMC% decreased, MDD increased and sub-grade soil Void Ratio decreased which indicates that JGT developed under the project was quite effective in strengthening weak sub-grade of roads.

Figure 9.1: Laying of JGT

Figure 9.2: Field CBR test at site

Figure 9.3: condition after 2 year of application

Figure 9.4: condition after 3 year of application

7. DESIGN GUIDELINE :

7.1. HILL SLOPE PROTECTION

Design concept in assessing contribution of open weave JGT for top soil erosion control is based primarily on its water-absorbing capacity for overland storage and the fabric thickness across the direction of run-off caused by precipitation for effecting successive reduction of run-off velocity. Kinetic Energy of rain drops causing detachment of top soil particles has also been considered The aspect of inter-penetration of water into the soil has not however been considered in this case being dependent on the hydraulic conductivity and saturation of the soil which is apt to

vary with the nature of slope fill. It is assumed that at some point on its path following the ground gradient, the velocity of run-off gets too weak to transport the detached soil particles. Thick strands of JGT (open weave) also trap and confine the detached soil particles partially.

The theoretical relations developed will lead to design the appropriate JGT for the purpose. It may be noted that the most important component of the fabric is the thickness of weft yarns both for overland storage and successive reduction of velocity of the run-off. There are other factors also in play such as ground friction, saturation of JGT. In fact the phenomenon is complex calling for comprehensive simulation study. The major factors have only been analyzedto prepare design guidelines

7.2.RIVERBANK PROTECTION

Bank soil may stabilize sufficiently if filtration is effective for at least two seasons usually. Experience gained over the years shows that stabilization of bank-soil depends on several factors viz severity of flow— especially its velocity, proximity to bank, change of direction as in tidal rivers, vortices at the bank-toe, waves and nature of influencing agents such as wind, tides. Bank protective measure with JGT may not be singly enough to withstand the impact of all the factors stated above for which structural interventions such as spurs may be necessary concurrently.

It is important to ensure durability of JGT till such time bank soil stabilizes optimally say, for three seasons. Special additives/treatment process developed by BJRI and IJIRA have been applied in the field with success.

The criteria for design therefore rests on the following viz; A) Design of JGT under site-specific conditions; B) Durability of JGT; C) Design of armour/riprap over JGT ensuring over-all stability of treated bank considering the tractive forces usually experienced under usual circumstances.

Design concept: The critical parameter for river bank erosion control is *the filtration capability* of the selected woven JGT. For filtration function to be effective under given hydraulic and geotechnical parameters, fabric design demands determination of optimal pore size of JGT that can retain the maximum soil particles ('soil tightness') on the one hand and ensure allowable permittivity to dissipate the pore water pressure in bank soil on the other. The design therefore should focus on AOS of woven JGT in relation to average grain size distribution of bank soil and permittivity of JGT vis-a-vis hydraulic conductivity of bank soil principally. There exist empirical relations for man-made geotextiles to address both the criteria. But then unlike man-made geotextiles JGT does not possess dimensional uniformity. Considering its lack of uniformity and for 'hairiness'of its yarns it is suggested that AOS of JGT was given a *larger tolerance* (say 15%) over the design value.Conceptually, designing a geotextile filter is no different from designing a graded granular conventional filter. For a geotextile to act as a filter, it is essential that a condition of equilibrium is established at soil-geotextile interface as soon as possible after its installation.A filter should prevent migration of soil particles to an acceptable degree, while at the same time allow pore water to flow though and also along the filter layer to prevent development of overpressure in bank soil. JGT filter was considered to meet the following criteria:

(1) The apparent opening size (AOS) of JGT usually denoted by O_{95}, should be less than the average particle size of the soil to be retained.
(2) The permeability of JGT, K_{JGT} should be sufficiently more than the permeability of soil, K_{SOIL} so that insignificant pore pressure can generate.
(3) The JGT must be capable of withstanding transportation and handling stresses.

7.3.RURAL ROAD CONSTRUCTION

Design of road pavement includes determination of its total thickness and thickness of the individual layers, i.e. the thickness of improved sub-grade, sub-base and base course layers. The total thickness of a pavement essentially depends on the strength of its sub-grade, axle load and number of load cycles.

Design approach for geotextile reinforced road pavement may be found available in different codes and methods suggested by different researchers. One of the popular methods suggested by Giroud and Noiray (1981) for synthetic geotextiles may also be adopted for jute geotextile (JGT) reinforced road pavement design. It may be appreciated that a JGT acts as an initial reinforcement until the initiation of its decomposition takes place. During this time, the strength of subgrade soil increases and presence of JGT becomes redundant for the future survivability of the road. Increase in shear strength of original subgrade due to use of JGT has been recorded by direct measurement of California

Bearing Ratio (CBR) at the field trial sites, both in Bangladesh and in India. From the test results, it is agreed that in less than twelve months' time the CBR value of subgrade soil increases by at least 1.5 times its original value. The required pavement thickness should be determined on the basis of the governing case between the analytical approach and the increased CBR value approach. It should be noted that JGT will be effective only if subgrade soil deforms adequately. Therefore, it is recommended that the proposed design approach be implemented for a subgrade soil having CBR value less or equal to 3.0%.

8. OBSERVATION AND DISCUSSIONS ON RESULTS:

8.1 Effect of JGT in soil moisture Hill Slope Protection

Monitoring was carried out at a regular intervals during monsoon and dry seasons for a period of about 3 years and results indicate that open weave JGT performed better than control sections. It is observed that run-off and nutrient loss was found least in 700 gsm OW JGT as compared to 500 gsm and 600 gsm. Average plant height and leaf area index of tea plantation is most favourable with 500 gsm OW JGT. At higher degree slopes, run-off and soil loss was found least in 700 gsm OW JGT. Fig 7 shows that soil loss at stiffer slopes (60 % and 90%) is least with OW JGT among 3 different types of geotextiles viz., Non woven synthetic, Non-woven JGT and OW JGT having same unit weight (500 gsm). It has been observed during monitoring for 3 years that soil loss was minimum for OW JGT as compared to non woven JGT, synthetic and control respectively. No rills or gully formation were observed at the JGT treated sections.

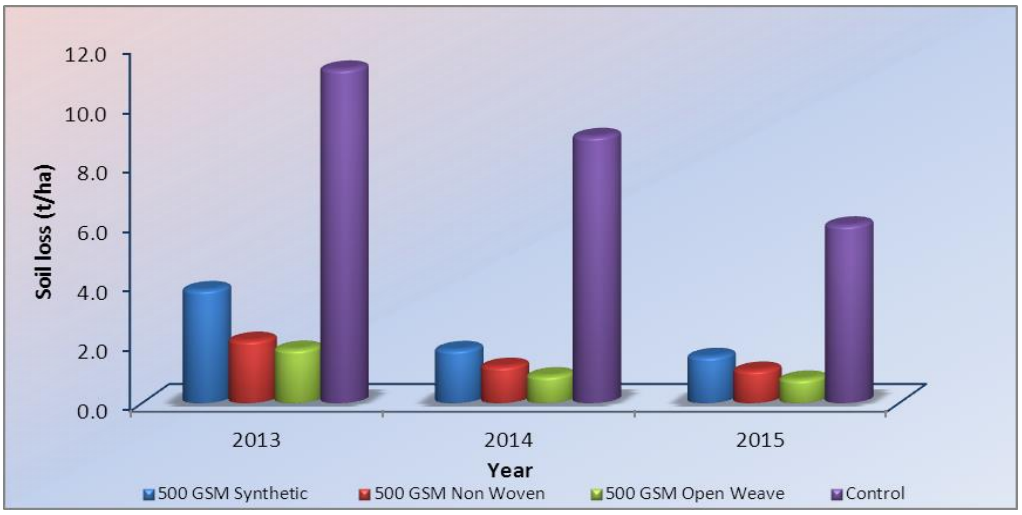

Figure 10: Soil loss (t/ha) at different duration under control and different type of geotextiles

8.2 RIVERBANK PROTECTION

Monitoring was carried out through at regular time intervals during monsoon and dry seasons for a period of about 5 years from 2011 to 2015 to understand the effects of application of JGT on bank surface. Due to fluctuations in water level during high flood and recession, water content within the bank soil showed variations.

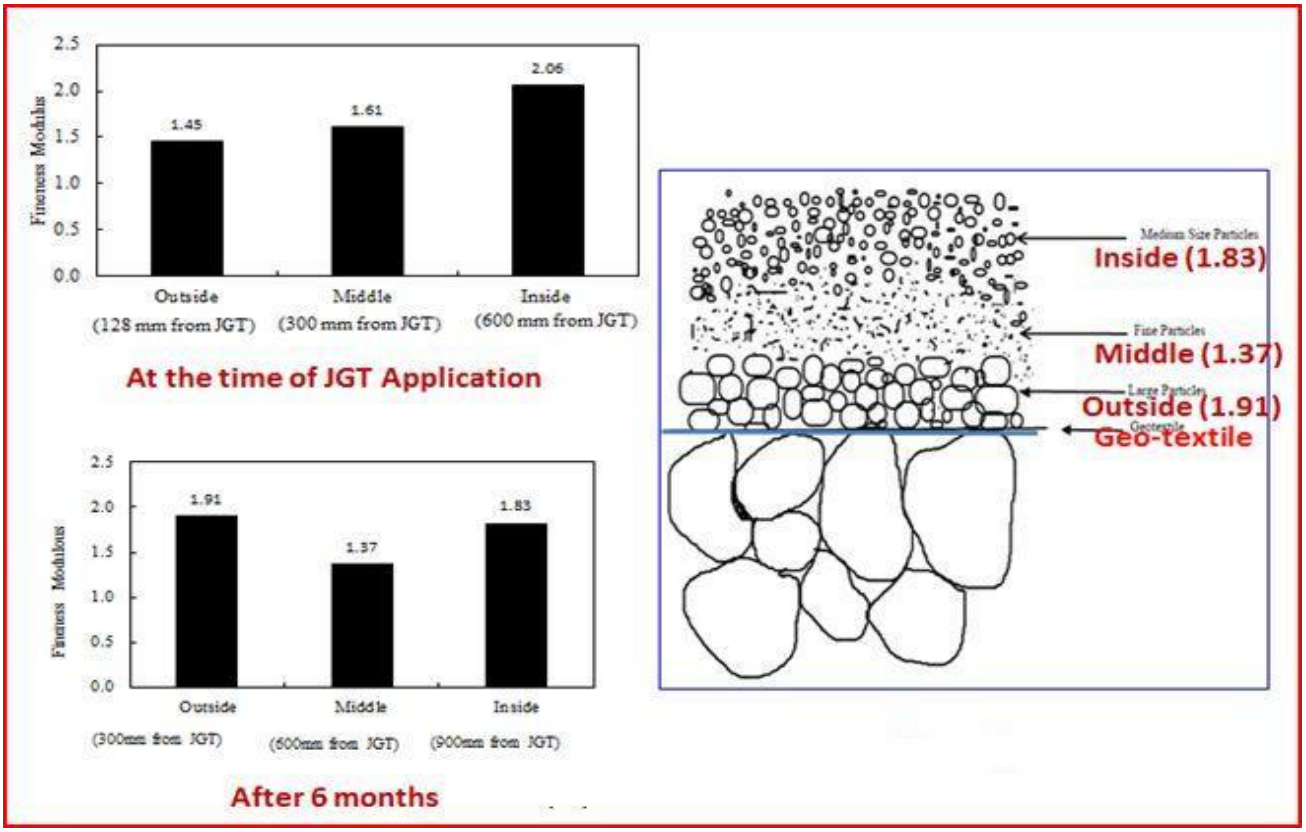

Figure 11: Fineness Modulus at the time of JGT Application and after 6 months of JGT Application

Fig 11 shows the gradual formation of filter cake with in bank soil particles implying re-arrangement of soil particles in a cake form. High Fineness modulus (FM) value at interface of JGT represents discontinued movement of smaller soil particles within bank soil itself thus controlling soil erosion. Visual observation shows the good quantity of vegetation growth that proves the stability of slope of river bank has been achieved. Structural intervention like spars etc. was necessitated to diverse flow that hugs to the bank.

8.3RURAL ROAD CONSTRUCTION

Figure Iand**II** are representing the variation of void ratio and dry density with time after treatment with JGT. Decrease of void ratio and increase of dry density with time is indicator of increased CBR% of sub-grade. Also the **Figure III** is indicating that the soaked CBR is gradually increasing with time, which can serve the road in better way. These data indicate that the application of JGT in rural road construction in appropriate way is effective.

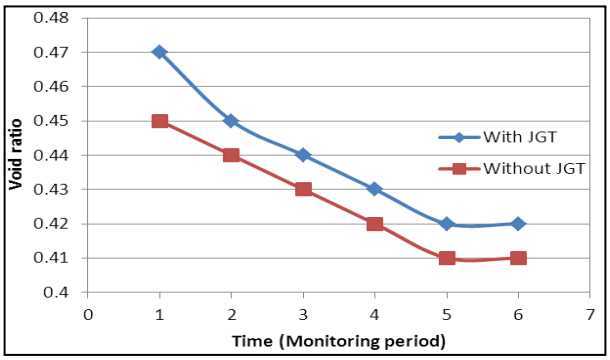

Figure 12.1 :Variation of Void Ratio with Time

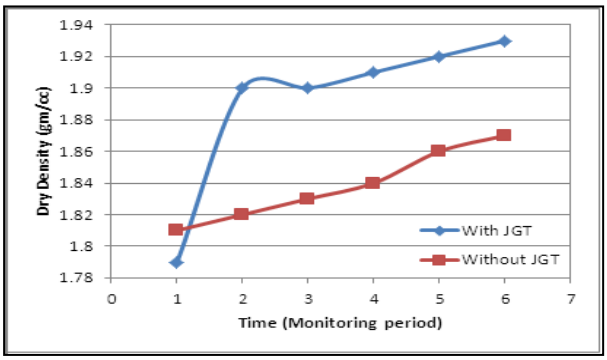

Figure 12.2: Variation of dry Density with

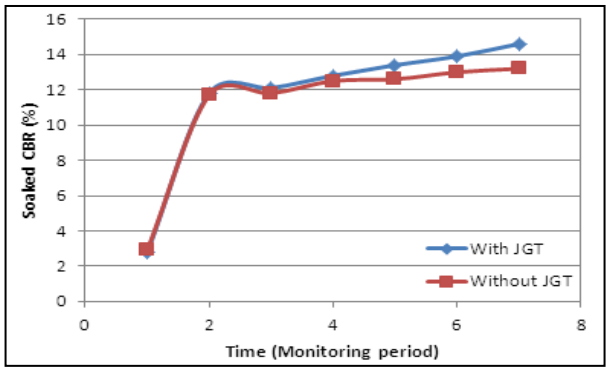

Figure 12.3 : Variation of Soaked CBR with Time

Monitoring was carried out through at regular time intervals for a period of about 3 - 4 years to understand the effects of application of JGT on sub-grade sub-base interface. The results were evident that depending upon soil characteristics and time of application of JGT, CBR values of sub-grade soil has increased significantly with increase in in-situ density of soil due to application of JGT. Fig 9.1 shows comparative resistance to penetration (load versus penetration) graph of JGT treated section and without JGT section.

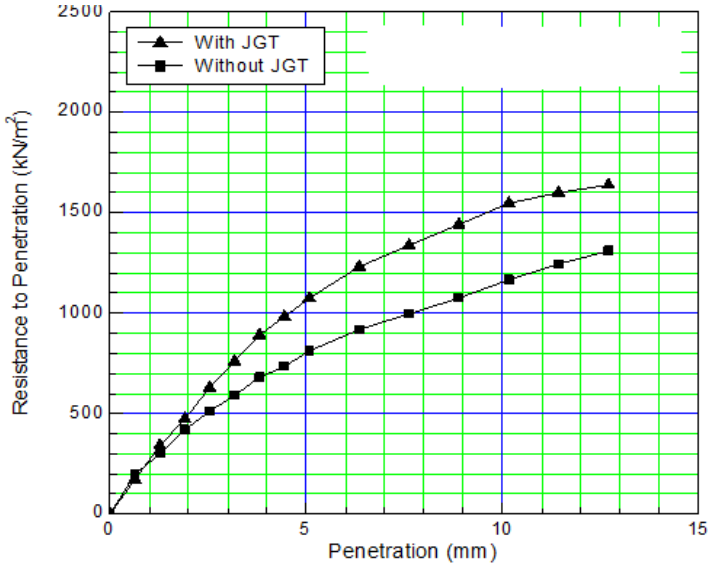

Figure 12.4: Load v/s Penetration curve of with JGT and without JGT portion

The measurement of the condition rating of Rural Roads was done by measuring Pavement Condition Index (PCI) which is recommended by National Rural Road Development Agency (NRRDA) as simple and low cost method. Accordingly 3 simple, low cost methods are suggested for the present, which can be done without much equipment.

i. ***Measurement based on Visual Inspection only***
Measurement based on Visual Inspection only

Description of Surface Condition	**PCI**
Very Good	5
Good	4
Fair	3
Poor	2
Very Poor	1

Visual Examination is based on presence of following distresses –

S.No.	Distress Type
1	Alligator Cracking
2	Block Cracking
3	Transverse Cracking
4	Joint Reflection Cracking
5	Patching
6	Potholes
7	Stripping

ii. ***Based on Riding Comfort***
A jeep or car is driven at 50 km/hr. and the riding comfort noted for each kilometre. Based on 'Riding Comfort' while driving at the design speed of 50 km/hr, the PCI is assessed as under:

Riding Comfort @ 50 km/hr.	**PCI**
Smooth and Pleasant Ride	5
Comfortable	4
Slightly Uncomfortable	3
Rough and Bumpy	2
Dangerous	1

iii. ***Based on comfortable Driving Speed possible***
The driver is instructed to drive at the most comfortable and safe speed possible on the road. The PCI then assessed for each kilometre based on the Normal Driving Speed, as under

Normal Driving Speed	**PCI**
Over 40 km/hr	5
30 to 40 km/hr	4
20 to 30 km/hr	3
10 to 20 km/hr	2
Less than 10 km/hr	1

PCI was measured at the end of each monitoring period and PCI calculated to be 15 (summation of above mentioned 3 criterion) for all roads treated with JGT except in few conditions where movement of heavy loaded commercial vehicles (of about 15 tonnes) passed.

8.3.1.THEORETICALANALYSIS USING ABAQUS ON RURAL ROAD

Verification of the results obtained from *ABAQUS* (FEM) with Theoretical One Layer Solution for Flexible Pavement: The 3D finite element model has been qualitatively verified in two aspects: i) Vertical stress at the top subgrade soil, ii) Vertical compressive strain measured at the top of subgrade soil under the center line of loading area.

For this purpose unreinforced rural road section for Nihinanagar to Hazratpur (UR NH) has been considered and stress and strain on the top of subgrade soil has been measured under tyre pressure of 550 kPa for a single wheel load. In this study elastic modulus of both top granular layers and subgrade has been defined as 20 MPa and a uniform Poisson's ratio of 0.4. Results measured from ABAQUS analysis has been compared with the theoretical solution available in after Ahlvin and Ulery (1962) for one layer pavement system. Vertical stress at top of sub-grade obtained from ABAQUS 6.1.1 and Ahlvin and Ulery (1962) are shown in **Figure IV.**

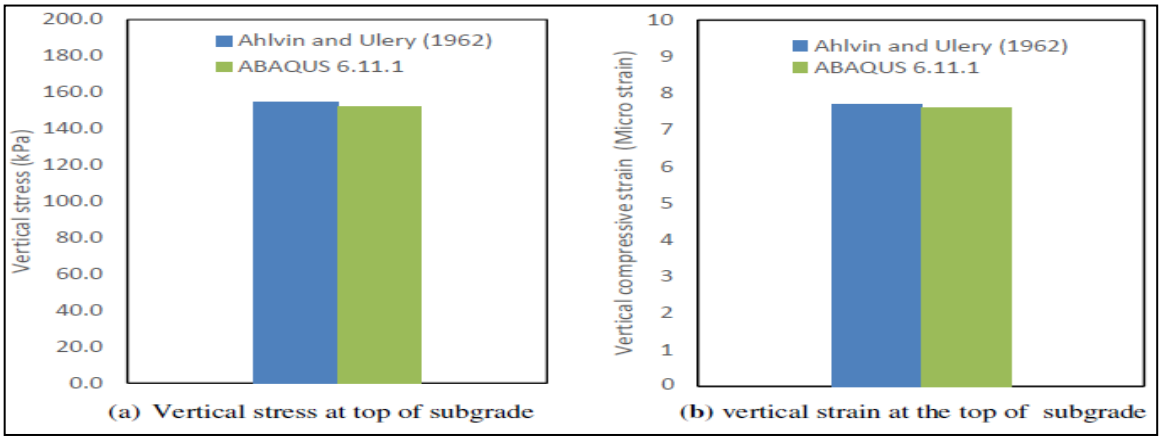

Figure 13: Comparison of Results Obtained from ABAQUS 6.1.1 and Ahlvin and Ulery

These are showing the vertical strain at the top of sub-grade soil. From both the figures it is found that results obtained from ABAQUS analysis shows good agreement with the theoretical solution. Data obtained from the finite element analysis performed using general purpose FEM software ABAQUS 6.1.1 indicted the development of vertical component of plastic strain under traffic passes of 1, 10, 100, 1000, 10000 cycles for the road sections considered in the present numerical study.

Rural road constructed on soft subgrade (CBR<3%) soil can causes excessive deformation of subgrade under traffic loading and leads to failure. It is observed that both the rural road sections reinforced with JGT and the rural road section after degradation of JGT reduces subgrade deflection considerably under traffic passes than the unreinforced .

Reduction in accumulated plastic strain of 100.00% indicates that no plastic strain has been accumulated in theJGT reinforced rural road section..Under traffic loading tensioned membrane effect of reinforcement (JGT) has been found which helps to decrease the stress magnitude coming on the top of sub-grade soil and reduces excessive deflection of the subgrade soil.

Results of the finite element study indicates that biodegradation of JGT does not affect its use as an sub-grade strengthening materialand it is also effective to reduce sub-grade deformation behaviour before and even after degradation of JGT.

9. PROJECT RESULTS ACHIEVED:

9.1.PwC conducted the market survey to assess the overall market and projected demand of JGT. The Jute industry supports nearly 40 lakh farmer families provide direct employment to 2.5 lakh industrial workers and livelihood to another 20 lakh people in secondary and tertiary sectors in the subcontinent alone. Increased demand of JGT would be a boost to this huge population. Geotextiles demand is expected to grow by a CAGR of nearly 10% from 870 million square metres in 2016 to around 1300 million square metres in 2020.

Indian domestic demand projection is on the back of a projected worldwide geo textile demand set to grow on an average at 8.5% CAGR by 2020. The potential sector-wise usage estimated for JGT in India in 2016 is around 35.25 million square metres.

Bangladesh government aimed to invest about Tk. 14,876 crore (US$ 1836 million) in developing the transport system. The industry in Bangladesh being the principal driver in global jute commodity trade however has of late been aggressively committing investments and providing policy impetuses in building domestic JGT capacities Per estimates of potential sector-wise usage even the most conservative estimates projects a yearly demand of 19.3 M sqm.

The international market for natural geotextile put together with Indian & Bangladesh is estimated to reach 870 M sqm in the year 2016, whereas the total potential of the entire Geotextile opportunity is considered would be higher at about 4880 M sq m in the year 2016.

9.2 DEVELOPMENT OF POTENTIALLY IMPORTANT JUTE GEOTEXTILES

Two varieties of woven JGT ie, 724 gsm for road construction & 627 gsm for erosion control of river bank and three varieties of OW JGT ie, 500 gsm , 600 gsm& 700 gsm for erosion control of slope were designed & developed by IJIRA and manufactured by jute industry successfully. The fabrics could meet the technical criteria as observed through vigorous testing at IJT geotextile testing laboratory.

National level standards on specifications of the JGTs developed under the project have been published by both India (IS 14715, Part I & II, 2016) and Bangladesh (BDS 1909 : 2016)

9.3. ENVIRONMENTAL IMPACTS ASSESSMENT

FINDINGS OF NSRI-

Having considered the environmental impact of producing three types of soil erosion control geotextiles (jute, coir and polypropylene), taking each stage of the product life cycle (from field agronomy to end of life), 100% jute and coir geotextiles exhibited low negative environmental impactandtheseare more environmental friendly than their man-made counterpart.

Another study suggest that jute products have the lowest cost followed by the coir while the synthetic products are of more than double the cost ofjute product. It appears that the jute products are the best for cost effective erosion control material taking into consideration all stages of their production and application.

A simulated study was conducted for rural road in experimental facility of NSRI, Cranfield University, UK incorporating 5 treatments, (1) control (no geotextile), (2) 20kN/m woven JGT, (3) 25kN/mwoven JGT, (4) geosynthetic and (5) control (no geotextile but thicker sub-grade). Specifications of the road construction conforms to IRC:SP:72:2007. Loaded wheel testing rig was set up for trial.

The orders of magnitude for the measured parameters (i.e. CBRs before and after application of loading), and the degree of surface deformation) for the 5 treatments were similar in the laboratory and the field. However, the ranking of the performance of the different treatments after the loading tests was not consistent between the field and simulations tests. However, whether the differences between the field and laboratory simulation tests are statistically significant cannot be tested due to the limited number of replicates.

The variance between the CBR and surface deformation results from the field trials and the laboratory simulation tests could be due to several reasons:

a) The simulation study was carried out in a covered area on a fixed track where the effects of filtration and drainage could not be evaluated.
b) The sub-grade soil encountered in the field trials could not be exactly simulated.
c) Soil consolidation being a time-dependent factor, scaled-down time for simulation will not reflect the ground realities experienced in field trials.

Simulated slope with rain-fall simulation arrangement have also been installed for corroboration of the results of field trials for slope erosion control. Three varieties of OW JGT were tried.
Overall Findings of NSRI is summarized below:

i) Time to run-off generation- Delayed due to application of JGT. Time depends on the type of soil
ii) Run-off volumes do not much differ with different types of JGT
iii) Different weights of JGT do not seem to affect control or generation of infiltration
iv) For total sediment yield weights of JGT are not statistically significant. JGT outperform Coir GT slightly in most tests
v) In the case of runoff velocity no noticeable difference was observed in the 3 types of OW JGT.

NSRI has observed that it could not compare the findings of the field trials due to lack of replication. But made it clear that JGT outperformed synthetic GT in controlling surface run-off & was found effective in controlling soil losses in a slope.

10. DISSEMINATION OF PROJECT RESULTS:

As of date India has organised / participated in **104** awareness programme on JGT and Bangladesh has done **26** such programmes. More than 40 technical documents / literatures on JGT has been published and circulated among the concerned engineers / decision makers(Annexure 2).

The findings of the project have been disseminated through seminar, workshop, exhibition, awareness programmes etc. Dissemination on interim findings has already been done through 2 National Workshops in 2013 at kolkata and 2014 at Dhaka. Results achieved at the end of 6th year (PY 6) of the project have also been disseminated through 2 more National Workshops held in May, 2016 at kolkata and in June, 2016 at Dhaka.

National Workshop on Jute Geotextiles (CFC/IJSG/21) held on May 30, 2016, IJIRA Conference Room, Kolkata, India

Dignitaries on the dais : L-R :- Mr. Arvind Kumar, Dr. Subrata Gupta ,Prof Nitin Som,Dr. U S Sharma

Inauguration- lighting the lamp

Welcome address by Mr. Arvind Kumar

Speech by Dr Subrata Gupta

Presentation by Prof. G Bhandari

Presen tation by Mr. P K Choudhury

National Workshop on Jute Geotextiles (CFC/IJSG/21) held on June 09, 2016, JDPC Conference Room, Dhaka, Bangladesh

Dignitaries on the dais: L-R:-Mr. IM Musa, Mr. N.Sengupta Ms.Nasima Begum, Mr.Quader Sarker, Mr. Asaduzzaman Quader, Mr. P.K.Choudhury

Welcome address by Mr. M I Musa

Speech by Ms. Nashima Begum

Address by Mr. N Sengupta

Speech by Prof: Abdul Jabbar Khan

Speech by Mr. M A Quader Sarkar

Presentation by Ms. Rumki Saha

Presentation by Mr. P K Choudhury

After successful completion of the two National Workshops, one in Kolkata and another in Dhaka, the International Seminar was held to disseminate the findings of the project and to exchange views to ultimately draw inference/ conclusion and make recommendation out of the project activities. Important dignitaries participated in the International Seminar from different organizations like, **JDPC (CI),**BUET, BJRI, & SRDI Bangladesh and NJB, MoT, Jute Mills, IJMA, IJIRA, IJT (DJFT-CU), WBSRRDA, CWC,CRRI,BIS, NRRDA, IIT, JU, Indian Railways, BRO, CSMRS, IISWRC, ICAR, CBIP, MNCFC, Geotech Consultants etc. from India. One Professor of University of Waterloo, Canada also actively participated in the Seminar.

International Seminar on Jute Geotextiles (CFC/IJSG/21) held during 22-23 June,2016, at the Conference Hall, Metropolitan Hotel , Delhi, India

Dignitaries on the dais, L-R : Prof. Abdul Jabbar Khan, Mr. Madhukumar Reddy, Mr. Arvind Kumar

Lighting the lamp by the dignitaries

Technical Exhibition

Glimpse of the delegates Glimpse of the delegates

Address by Dr. Subrta Gupta

Address by Prof. Abdul Jabbar Khan

Address by Dr. I K Pateriya

Release of book of papers

Presentation by Mr. J K Gupta

Presentation by Mr. P K Choudhury

Speakers on the dais with session chairman, Prof. S Mittal

Valedictory session

However, based on findings of encouraging results and interest shown by the end users / academicians both the countries are planning to organize awareness Workshop / Seminar in the district and state levels within and outside the country even after completion of the project in view of popularizing JGT among the user agencies to ensure usages of JGT in large scale throughout the country and beyond.

11. LESSONS LEARNED

The most significant lessons emerging from the project concern are - a) Development of strategies for improving the supply chain mechanism b) Conducting laboratory simulation under different soil and static as well as dynamic

loading conditions c) Development of design methodologies with JGT for different applications in corroboration with other international standards d) Development of improved / efficient process/production techniques (fabric engineering) for wider scale manufacturing of JGT e) Formulation of standards / strategies for the selected and produced JGT for global acceptance. f) effect of biodegradability of JGT on improvement of soil behaviour under different soil conditions.

11.1 Development Lessons

The project was designed in such a manner that most appropriate JGT identified for specific applications could be implemented in the actual field condition to achieve the desired results. It was learnt from the project that the design for erosion control of hill slope & river bank as well as road construction should not be a typical theoretical design, rather all the practical aspects should be considered in the design. Sufficient pre-work site features and soil data needs to be collected and analysed for preparing site specific appropriate design for the future projects.

11.1.1 Hill Slope Protection

Design concept in assessing contribution of open weave JGT for top soil erosion control is based primarily on its water-absorbing capacity for overland storage and the fabric thickness across the direction of run-off for effective successive reduction of run-off velocity. Depending upon rate of precipitation, nature of soil, infiltration rate, slope gradient, slope length thicker yarns of fabric contribute to entrapment of detached soil particles thereby protecting the slope.

11.1.2 Riverbank Protection

JGT should be recommended for mild rivers both in unidirectional and tidal flow having sandy silt, silty clay and claye silt type of bank soil and it was observed that soil migration has been checked due to initiation in formation of filter cake within the bank soil. JGT will be effective even in place of meanders, if adequate length of apron is designed as per specifications.

11.1.3 Rural Road Construction

Quality of JGT should be decided based on design by functional properties of a particular road. JGT developed under the project is recommended for low volume roads having silty clay, clayey silt and silty sand type of soil even under enhanced traffic load (Cumulative Equivalent Standard Axle Load (ESAL) of 60,000 – 1,00,000) over design period under low to high annual rain fall conditions.

11.2 Operational Lessons

In India and Bangladesh all the application sites like hill slope, river bank and roads identified for application of JGT were on public grounds that are government owned. Hence, the choice of a site did not depend on the technology provider but on respective Government Departments. During implementation of the project a few number of operational problems were encountered as indicated below:

1) Pre-conceived idea / mind set of the concerned engineers due to lack of awareness on JGT, 2) Absence of JGT as an item of work in the Schedule of Rates (SoR), 3) Encroachment of right of way in case of road, 4) Testing of borrowed earth / fill material used in sub-grade of road, 5) Price fluctuation of JGT and construction materials, 6) Difficulty in acquiring required land for making gentle slope (depending on angle of internal friction of soil), 7) Construction of road in a proper way sometimes became difficult due to movement of vehicles before the road has been completed and declared open to traffic, 8) Absence of proper access to the site and insufficient storage facility of construction materials including JGT and 9) Inadequate quantity and quality of construction materials available at site affects completion of work on time.

The above mentioned situations could be overcome if proper planning is made during preparation of a Detailed Project Report (DPR) / Scheme Booklet prior to implementation of the project.

12. CONCLUSIONS AND RECOMMENDATIONS

a) Both Bangladesh and India have successfully implemented the project in the areas of erosion control of slope of hill & river bank and road construction and came out with encouraging results.

b) Potentially important JGTs were designed & developedin such a manner that any jute mill can manufacture any variety of JGT by utilizing the existing machinery. The products were tested as per standard testing methods and the results could meet the set parameters.

c) The fabric specifications were standardized and published by standard making authorities of both countries (Bangladesh- BDS 1909:2016 and India- IS 14715, Part I & II: 2016). Products have also been included as item of work in the Schedule of Rates (SoR) by different Government departments in both the countries.

d) Design methodologies and installation guidelines have been prepared.

e) Demand of JGT is likely to reach 1300 million sqm. By2020.There will be no dearth in manufacture & supply of JGTs developed under the project by the jute mills in both the countries.

f) OW JGT (500-700 gsm) is capable to control erosion of hill slope effectively. Soil moisture retention is higher in case of higher weight of JGT, erosion of soil is minimum in case of 600 gsm JGT. For tea plantation 500 gsm was most effective. Soil loss was found minimum in OW JGT as compared to both nonwoven JGT and nonwoven synthetic geotextile having the same weight (500 gsm).Some structural interventions like, toe-wall, berm etc. is recommended in place of steep slope as lateral restraint for slope stability.

g) 20 kN/m tensile strength treated woven JGT is quite effective for river bank erosion control for mild rivers by forming filter cake with bank soil. In case of high velocity river additional structural measures like spur, groynes etc. are needed at high erosion prone bank.

h) 25 kN/m tensile strength woven JGT of 724 gsmcould strengthen the road sub-grade remarkably by increasing field CBR% by more than double with enhancement in field dry density with time under different traffic loading and rain fall conditions.

i) OW JGT outperformed coir and synthetic geotextiles in controlling soil erosion of slope.JGT is much cheaper than coir and synthetic erosion control materials. Jute and coir geotextiles exhibit positive environmental impact while the synthetic geotextiles have significantly negative environmental impact.

j) Interests in using JGT by various Government departments in both countries are increasingand it is expected that it will ultimately help the jute mills workers and farmers for their livelihood and alleviate poverty level.

k) As the end users are showing interest to use JGT, the ongoing awareness programme to disseminate results and findings of the study under the project among the geotechnical engineers and decision makers of the government departmentswill be continued in massive way all over the world to popularise JGT.

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ANNEXURE

Table1: SPECIFICATIONS OF WOVEN & OPEN WEAVE JUTE GEOTEXTILES

Construction	Woven JGT for road construction	Woven JGT for river bank protection	Open weave JGT for slope stabilisation		
Width (cm)	≥ 200 cm	≥ 200 cm	≥ 122 cm		
Weight (gsm) at 20% MR	724 (±5%)	627 (±5%)	500 (±10%)	600 (±10%)	700(±10%)
Ends X Picks / dm	≥ 94 X 39	≥ 85 X 32	≥ 6.5 X 4.5	≥ 8 X 7	≥ 8 X 8
Thickness (mm)	1.85 (±10%)	1.70 (± 10%)	4.50 (±10%)	5.25 (±10%)	5.50(± 10%)
Wide width Tensile strength (kN/m) MD XCD	≥ 25 X 25	≥ 20 X 20	≥ 6.5 X 6	≥ 12 X 6	≥ 14 X 7
Elongation at break (%)MD X CD	≤ 12 X 12	≤ 12 X 12	≤ 14 X 14	≤ 14 X 14	≤ 14 X 14
Puncture Resistance (kN)	0.500(±10%)	0.400 (±10%)	-	-	-
Burst Strength (KPa)	3500 (±10%)	3100 (± 10%)	-	-	-
Permittivity at 100 mm constant head (/s)	0.35 (± 10%)	0.35 (± 10%)	-	-	-
A.O.S. (Micron) O95	150 - 400	150 - 400	-	-	-
Open Area (%)	-	-	50 - 65	45 - 50	40 - 45
Water Holding Capacity (%) on dry weight	-	-	450 - 500	450 - 500	550 – 600

Table 2: SITE WISE APPLICATION OF JGT

Type of application	India	Bangladesh	Total
Hill slope protetction	5	3	8
Riverbank Protection	6	5	11
Rural Roads	7	6	13

SL No.	Application sites	Undertaken by
Indian sitesfor Hill Slope Protection: Total Number of sites 5 (3+2)		
1.	Effectiveness of Jute Geotextile in Rehabilitation of Severely Degraded Hill Slope of Punjab Shivaliks	Indian Institute of Soil & Water Conservation (IISWC),Chandigarh
2.	Field Trial Application of Jute Geotextiles (JGT) for Hill	Indian Institute of Soil & Water

SL No.	Application sites	Undertaken by
	Slope Management, Deharadun	Conservation (IISWC), Dehradun
3.	1st Prototype Study on Efficacy of Jute Geo-Textiles for Hill Slope Stabilization Using Tea Plants as Test Crop, Udhagamandalam	Indian Institute of Soil & Water Conservation Research Centre (IISWC), Udhagamandalam
4.	2nd Prototype Study on Efficacy of Jute Geo-Textiles for Hill Slope Stabilization on Varying Slope Using Grass, Udhagamandalam	Indian Institute of Soil & Water Conservation Research Centre (IISWC), Udhagamandalam
5.	Field Trial Application of Jute Geotextiles (JGT) for Hill Slope Management at Kerayada Site Undertaken, Udhagamandalam	Indian Institute of Soil & Water Conservation Research Centre (IISWC), Udhagamandalam
Bangladesh site for Hill Slope Protection: Total Number of Activities 3 (2+1)		
1.	Efficacy of Jute Geotextiles for Alikadam - Thanchi Road (Downhill 10.8 Km) Hill Slope Management	Jute Diversification Promotion Centre (JDPC), Ministry of Textiles and Jute, Government of the People's Republic of Bangladesh,BUET and Special Works Organization (SWO) BD Army.
2.	Efficacy of Jute Geotextiles for Alikadam - Thanchi Road (Downhill 11.7 Km) Hill Slope Management	
3.	Efficacy of Jute Geotextiles for Alikadam - Thanchi Road (Uphill 14.75 Km) Hill Slope Management	
Indian sites for Riverbank Protection: Total Number of sites 6		
1.	Bhagirathi River Bank Protection Work, Shantipur, WB	Irrigation & Waterways Directorate, Government of West Bengal
2.	Dharala River Bank Protection Work, Coochbehar, WB	
3.	Fulahar River Bank Protection Work, Malda, WB	
4.	Jagaddal River Bank Protection Work, S 24 Parganas, WB	
5.	Kaljani River Bank Protection Work, Coochbehar, WB	
6.	Punarbhava River Bank Protection Work, Coochbehar, WB	
Bangladesh sites for Riverbank Protection: Total Number of sites 5		
1.	Ghaghat River Bank Protection Work	Bangladesh Water Development Board initiated by Jute Diversification Promotion Centre (JDPC), Ministry of Textiles and Jute, Government of the People's Republic of Bangladesh
2.	Gorai River Bank Protection Work	
3.	MBR Channel River Bank Protection Work	
4.	Pathoraj River Bank Protection Work	
5.	Sakhbaria River Bank Protection Work	
Indian sites for Rural Road: Total Number of sites 7		
1.	Rural Road (India Part): V. Koracharahatti to T-10 Road, Davanagere, Karnataka	State Rural Road Development Agency (SRRDA) under PradhanMantri Gram SadakYoyona (PMGSY)
2.	Rural Road (India Part): Devarahospet to Gundur, Havery, Karnataka	
3.	Rural Road (India Part):BagdimarimuloBaradanagar to DamkalKheyaGhat, S 24 Parganas, WB	
4.	Rural Road (India Part):Nihinagar to Hazratpur, S Dinajpur, WB	
5.	Rural Road(India Part): Kanksa to Bati, Mursidabad, WB	
6.	Rural Road(India Part): Promod Nagar to Muga Chandra Para, West Tripura	
7.	Rural Road(India Part): Udal to Chakbrahma, S Dinajpur, WB	
Bangladesh sites for Rural Road: Total Number of sites 6 (5+1)		
1.	Turag – Rohitpur - Baurvita (Keraniganj) Rural Road Construction Work	Local Government Engineering Department (LGED) and Roads & Highways Department (RHD) initiate by Jute Diversification Promotion
2.	Circular Road at Savar Cantonment (Savar) Rural Road Construction Work	

SL No.	Application sites	Undertaken by
3.	BancharampurSouthpara (Kandapara) Road, Brahmanbaria Rural Road Construction Work	Centre (JDPC), Ministry of Textiles and Jute, Government of the People's Republic of Bangladesh
4.	Tezkhali - Titas (Bishnurampur) Rural Road Construction Work	
5.	Noabenki-Gazerhat-Harihajanhat Road (Shymnagar, Satkhira) Rural Road Construction Work	
6.	SairborG$_c$ To MithapurG$_c$ Via Lahuria Bazar Road (Lohagara, Narail)Rural Road Construction Work	