Research Journal of Engineering Sciences ____ ISSN 2278 – 9472
Vol. **3.(1),** 1-12, January **(2014)** *Res. J. Engineering Sci.*

Development of Jute Geotextiles in Combating Geotechnical Problems

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Available online at: www.isca.in, www.isca.me
Received 24th December 2013, revised 11th January 2014, accepted 26th January 2014

Abstract

Geotextiles made of natural fibres like jute have been found to be effective in improving geotechnical characteristics of soil and are being extensively used for various technical end-uses viz. rural road construction, protection of river banks, stabilization of embankments, erosion control, management of slopes, consolidation of soft soils etc.Over the years several research and developmental studies alongwith different projects of national and international status have been carried out to establish the efficacy of jute geotextile (JGT) in satiating the geotechnical requirements. One such encouraging response is CFC/IJSG/21 Project, funded by Common Fund for Commodities, Netherlands and its execution is being carried out jointly by the two neighbouring countries India and Bangladesh. The overall objective of the project is to determine and demonstrate the effectiveness of jute geotextile in the two pre-identified promising applications like rural road construction and soil erosion control to demonstrate their competitiveness with the otherman-madematerials generally in use. In execution of the project, Department of Jute and Fibre Technology (DJFT), University of Calcuttahad been mainly entrusted with the testing of the different samples produced by the different Jute Mills of West Bengal, India as per the specifications laid by National Jute Board, Ministry of Textile, Govt. of India, the Project Executing Agency (PEA). DJFT has carried out all of the testing work of the woven JGT samples required for the specified geotechnical applications and made a comprehensive test report and comparative analysis of the test results. The Project Investigator has shared the test results with the PEA, time to time, alongwith the different Facilitating Agencies (FAs) of India for the purpose of finalisation of specification of the Jute Geotextile for the above mentioned three specific applications. The testing of the developed JGT samples of different functional categories is followed by respective field trials along with vigilant monitoring process at different sites to evaluate their performance for the purpose of standardization of the same to fulfil the requirement of global acceptance.One of the prime criteriafor global recognition of the reports and analysis of the test results of the samples carried out by any laboratory is to get accredited by a statutory certifying body of national or international status following anytesting standard like ASTM, CEN etc. Heading in this direction, DJFT, IJT, CU has already undertaken a project under the supervision of National Jute Board (NJB), MoT, GoI alongwith Indian Rubber Manufacturers Research Association (IRMRA), Mumbai, India, as consulting agency to get their geotextile laboratory National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited and is undergoing the procedurefor getting NABL certified. The testing of the exhumed samples is also taking place simultaneously for assessing the performance andsustainability of the developed products.

Keywords: Jute Geotextile, ASTM standards, geotechnical engineering, NABL, CEN.

Introduction

From the very inception of the Indian Jute Industry, jute fibre has proved its superiority over other fibres particularly in the area of packaging for food grains, in terms of its functionality and reusability due to its considerable tensile strength, low extensibility and good dimensional stability, which is obviously the natural choice for packaging[1-3]. One of the growing alternatives in today's context is the emergence of technical textiles made out of natural fibres which includes geotextile products for geotechnical applications, agrotextile products as well as other such relevant areas[4-6]. Jute geotextile (JGT) can certainly be considered as a potential aspirant replacing majority of today's popular synthetic products which are posing severe threats to our environment thereby adversely affecting the eco-congruity[7-15]. Several exhaustive studies and research works related to the design and engineering of JGTs with end-use requirements have been carried out over the years by several research organizations of national and international status to establish the potentiality of JGTs in mitigating the geotechnical problems[4-15].Presently one such project named CFC/IJSG/21 Project, funded by Common Fund for Commodities, Netherlands is one such sincere and promising endeavour headed with the goal of "Development and application of potentially important Jute Geotextile"[16] with the purpose to achieve the objectives which are commercial acceptability of potentially important Jute Geotextile suitable for use in two identified end uses namely soil erosion control and rural road construction in the context of condition prevalent in India and Bangladesh, development of material specification, field application / installation protocols and design methodology or these applications in compliance with requirements and standards set by public and private sector users, market needs assessments and compliance studies.In execution of the above mentioned objectives DJFT, IJT, CU[16] has been entrusted to collect random samples from the entrusted mills in India, to test them in its laboratory and to characterize materials.DJFT has been bestowed with the responsibility to design appropriate fabrics for the two specific applications of rural road construction and protection of river banksfollowed by advising the mills on quality control and production of JGT on the basis of inputs provided by Bengal Engineering and Science University (BESUS), Shibpur, West Bengal, and other implementing / facilitating agencies of the project. Moreover, DJFT has to share with BESUS in India the result of tests and associate with the said institution in finalization of specification for potentially important JGT for the above stated two specific applications.

Materials and Methods

Earlier, in order to promote the JGT in a bigger way twill weave JGT were use in road construction as underlay, on an experimental basis in the then Pradhan Mantri Gram Sadak Yojna (PMGSY) Project. To achieve the prime property parameters liketensile strength and porometry property parameters higher area density of Twill weave JGT having 700-1000 gsm were used in the PMGSY Project. But the field trial performance of the twill weave fabric was not found to be encouraging.From the previous experience the Project Executing Agency (PEA) alongwith the Facilitating Agency (FA) have chosen DW Plain Weave Fabric of lower area density as this fabric meets the tensile strength and porometry required for road construction.Moreover ease of production of DW Plain fabric than that of Twill weave fabric affirms the choice of DW Plain weave fabric. Selection of using double warp in place of single warp helped to achieve higher tensile strength and also moderated chances of minimizing reed marks which affects porometry of the fabric.On this basis the PEA has set sample specifications of woven and open weave fabrics which were supplied to the different Jute Mills and were asked to supply the samples as per the specifications as provided in table-1 and table- 2 respectively.

Results and Discussions

On the basis of the supplied specifications by PEA, twenty-six samples of woven JGT of five different constructions for rural road / river bank protection and twelve samples of open weave JGT of four differentconstructions for hill slope protection were collected from eightandfour jute mills respectively as furnished in Tables 3 to 6 and Tables 7 to 10 respectively.

Table-1
Sample specifications for Woven JGT supplied to the Jute Mills by PEA (NJB)

Construction	Double Warp Plain Weave (DW Plain)			
Width (cm)	100 cm			
Tensile Strength (kN/m) MD X CD	25 X 25			
Fabric weight (gsm)	627	665	724	760
Porter X Shots	10 X 8	9 X 9	11 X 10	12 X 10
Ends X Picks / dm	85 X 32	77 X 35	94 X 39	102 X 39
Warp Count (lbs/spy)	10.00	11.00	10.00	9.75
Weft Count (lbs/spy)	28.00	28.00	27.00	28.00
Q. R. of Warp	0.80	0.80	0.80	0.80
Q. R. of Weft	0.75	0.75	0.75	0.75

Table-2
Sample specifications for Open Weave JGT (Soil Saver) samples supplied to the Jute Mills by PEA (NJB)

Construction	Open weave jute soil saver			
Width (cm) min.	122			
Fabric weight (gsm)	365 (with thicker weft and thinner warp yarn)	500 (with thicker weft and thinner warp yarn)	600	700
Ends X Picks / dm	5 X 4	6.5 X 4.5	7 X 6	7 X 7
Warp Count (lbs/spy)	65	75	128	138
Weft Count (lbs/spy)	170	200	128	138

Table-3
Comparison of Test Results - Woven JGT Samples (Range of area density 600-650 gsm)

Parameters	Converted Mass @ 20% M.R. (gsm)	Ends/dm X Picks /dm	Thickness (mm)	Tensile Strength (kN/m), [Warp X Weft] and Elongation (%) [Warp X Weft]	Index Puncture (kN)	Bursting Strength (kg/cm^2)	Permittivity (/sec)	AOS (Micron), (O_{95})
Mill No. 01	642.66	86.5 X 32.0	1.79	22.24 X 22.79 9.0 X 6.0	0.41	28.07	1.10	280
Mill No. 02	626.44	81.0 X 32.5	1.53	20.83 X 23.99 9.0 X 7.0	0.37	26.20	1.74	500
Mill No. 03	632.2	79.0 X 38.0	1.45	28.87 X 25.06 9.0 X 9.0	0.51	27.75	1.14	460
Mill No. 04	—	—	—	—	—	—	—	—
Mill No. 05	605.0	82.0 X 30.0	1.58	22.37 X 13.65 9.0 X 9.0	0.45	23.10	3.20	720
Mill No. 06	634.0	84.0 X 32.0	1.48	23.17 X 27.55 10.0 X 8.0	0.44	28.3	0.86	385
Mill No. 07	614.0	80.0 and 32.0	1.73	21.07 X 17.30 7.0 X 7.0	0.48	25.68	1.48	770
Mill No. 08	—	—	—	—	—	—	—	—

Table-4
Comparison of Test Results - Woven JGT Samples (Range of area density 650-700 gsm)

Parameters	Converted Mass @ 20% M.R. (gsm)	Ends/dm X Picks /dm	Thickness (mm)	Tensile Strength (kN/m), [Warp X Weft] and Elongation (%) [Warp X Weft]	Index Puncture (kN)	Bursting Strength (kg/cm^2)	Permittivity (/sec)	AOS (Micron) (O_{95})
Mill No. 01	657.00	77.0 X 36.0	1.73	17.51 X 22.98 11.0 X 7.0	0.45	26.6	1.79	255
Mill No. 02	655.11	77.0 X 35.0	1.57	17.75 X 26.55 10.0 X 7.0	0.46	26.5	1.55	480
Mill No. 03	—	—	—	—	—	—	—	—
Mill No. 04	—	—	—	—	—	—	—	—
Mill No. 05	672.0	97.0 X 36.0	1.42	25.08 X 21.92 10.0 X 9.0	0.36	27.20	1.04	245
Mill No. 06	648.0	75.0 X 34.0	1.49	19.78 X 31.67 10.0 X 9.0	0.52	29.10	0.69	350
Mill No. 07	672.0	97.0 X 36.0	1.42	25.08 X 21.92 10.0 X 9.0	0.36	27.20	1.04	245
	621.0	77.0 X 36.0	1.43	18.68 X 18.87 9.0 X 8.0	0.46	26.13	1.11	385
Mill No. 08	680.0	84.0 X 39.0	1.55	23.70 X 22.50 9.0 X 7.0	0.55	23.96	1.13	390
	696.0	76.0 X 35.0	1.50	21.80 X 31.50 9.0 X 8.0	0.54	29.20	1.04	350

Table-5
Comparison of Test Results - Woven JGT Samples (Range of area density 700-750 gsm)

Parameters	Converted Mass @ 20% M.R. (gsm)	Ends/dm X Picks /dm	Thickness (mm)	Tensile Strength (kN/m), [Warp X Weft] and Elongation (%) [Warp X Weft]	Index Puncture (kN)	Bursting Strength (kg/cm^2)	Permittivity (/sec)	AOS (Micron) (O_{95})
Mill No. 01	716.88	91.0 X 39.0	1.68	21.88 X 27.62 11.0 X 7.0	0.52	26.5	0.83	195
Mill No. 02	752.00	92.0 X 38.0	1.73	30.93 X 21.75 6.0 X 14.0	0.49	33.3	0.59	260
Mill No. 03	716.2	92.0 X 39.0	1.54	24.85 X 27.36 12.0 X 6.0	0.42	21.02	0.85	240
Mill No. 04	724.00	96.0 X 36.0	1.78	23.25 X 27.77 11.0 X 11.0	0. 52	27.08	0.82	270
Mill No. 05	795.00	91.0 X 39.0	1.51	21.32 X 28.56 13.0 X 8.0	0.54	28.42	0.30	175
Mill No. 06	768.0	90.0 X 38.0	1.63	19.70 X 33.53 14.0 X 8.0	0.61	30.40	0.42	175
Mill No. 07	—	—	—	—	—	—	—	—
Mill No. 08	758.0	83.0 X 40.0	1.65	20.00 X 27.10 15.0 X 7.0	0.53	29.70	0.81	237

Table-6
Comparison of Test Results - Woven JGT Samples (Range of area density 750-800 gsm)

Parameters	Converted Mass @ 20% M.R. (gsm)	Ends/dm X Picks /dm	Thickness (mm)	Tensile Strength (kN/m), [Warp X Weft] and Elongation (%) [Warp X Weft]	Index Puncture (kN)	Bursting Strength (kg/cm^2)	Permittivity (/sec)	AOS (Micron), O_{95}
Mill No. 01	736.66	99.0 X 39.0	1.58	22.90 X 28.86 12.0 X 6.0	0.47	27.8	0.23	175
Mill No. 02	760.00	100.0 X 35.0	1.82	20.06 X 30.23 14.0 X 7.0	0.63	27.7	0.47	185
Mill No. 03	780.00	100.0 X 40.0	1.83	24.76 X 21.64 14.0 X 6.0	0.42	23.10	0.58	235
Mill No. 04	809.00	97.0 X 39.0	1.44	22.39 X 38.32 12.0 X 7.0	0.61	24.82	0.21	167
	846.0	99.6 X 40.6	2.11	25.50 X 30.05 19.0 X 8.0	0.72	30.40	0.49	207
Mill No. 05	814.00	95.0 X 37.0	1.51	24.59 X 29.60 12.0 X 8.0	0.59	31.42	0.19	130
Mill No. 06	772.0	99.0 X 38.0	1.57	20.68 X 32.3715.0 X 8.0	0.62	33.60	0.34	175
Mill No. 07	721.0	86.0 X 38.0	1.58	23.27 X 22.90 12.0 X 7.0	0.55	27.13	0.92	245
Mill No. 08	785.0	102.0 X 39.0	1.60	23.80 X 27.30 12.0 X 7.0	0.74	25.36	0.70	265
	820.0	99.0 X 40.0	1.63	22.60 X 34.90 13.0 X 8.0	0.64	32.70	0.72	245

Table-7
Comparison of Test Results –Open Weave JGT (Soil Saver) Samples (Range of area density 350-450 gsm)

Parameters	Width (cm)	Converted Mass @ 20% M.R.	Ends/dm X Picks /dm	Thickness (mm)	Tensile Strength (kN/m), [Warp X Weft]andElongation (%),[Warp X Weft]	Open Area (%)
Mill No. 01	—	—	—	—	—	—
Mill No. 02	122.0	414.0	6.0 X 5.0	4.47	4.25 X 6.63,11.0 X 16.0	62.4
Mill No. 03	121.2	420.0	6.0 X 5.0	4.32	8.59 X 3.58,8.0 X 22.0	53.00
Mill No. 04	—	—	—	—	—	—

Table-8
Comparison of Test Results – Open Weave JGT (Soil Saver) Samples (Range of area density 450-550 gsm)

Parameters	Width (cm)	Converted Mass @ 20% M.R.	Ends/dm X Picks /dm	Thickness (mm)	Tensile Strength (kN/m), [Warp X Weft] and Elongation (%),[Warp X Weft]	Open Area (%)
Mill No. 01	122.0	467.0	7.0 X 5.0	3.81	7.00 X 4.66, 10.0 X 8.0	51.11
Mill No. 02	122.0	482.22	7.0 X 5.0	4.62	6.34 X 5.74,11.0 X 12.0	55.87
	122.0	536.0	7.0 X 5.0	4.96	4.85 X 5.55, 16.0 X 16.0	51.1
	123.0	558.0	6.5 X 5.0	4.46	3.70 X 6.68,14.0 X 14.0	51.32
Mill No. 03	120.0	627.55	7.0 X 5.0	5.22	18.38 X 4.22,7.0 X 16.0	51.00
Mill No. 04	124.0	583.00	7.0 X 5.5	5.25	7.68 X 8.73,9.0 X 10.0	47.5

Table-9
Comparison of Test Results –Open Weave JGT (Soil Saver) Samples (Range of area density 550-650 gsm)

Parameters	Width (cm)	Converted Mass @ 20% M.R.	Ends/dm X Picks /dm	Thickness (mm)	Tensile Strength (kN/m), [Warp X Weft] and Elongation (%),[Warp X Weft]	Open Area (%)
Mill No. 01	—	—	—	—	—	—
Mill No. 02	122.0	593.11	8.0 X 7.0	5.47	11.76 X 6.19, 7.0 X 12.0	48.00
	122.0	606.00	7.5 X 6.5	4.52	9.23 X 6.00,10.0 X 10.0	51.5
	122.0	675.00	7.0 X 6.0	4.98	9.72 X 7.65,11.0 X 13.0	52.91
Mill No. 03	122.0	672.50	7.0 X 7.0	5.24	15.84 X 6.21,11.0 X 18.0	47.00
Mill No. 04	124.0	633.00	8.0 X 6.5	4.69	14.07 X 8.37, 9.0 X 11.0	41.00

Table-10
Comparison of Test Results–Open Weave JGT (Soil Saver) Samples (Range of area density 650-750 gsm)

Parameters	Width (cm)	Converted Mass @ 20% M.R.	Ends/dm X Picks /dm	Thickness (mm)	Tensile Strength (kN/m),[Warp X Weft] and Elongation (%),[Warp X Weft]	Open Area (%)
Mill No. 01	122.0	699.0	7.5 X 8.0	4.66	16.86 X 9.98,9.0 X 10.0	41.50
Mill No. 02	122.0	713.3	8.0 X 8.0	5.30	14.38 X 6.98,8.0 X 13.0	40.30
	122.0	660.0	7.5 X 7.5	5.47	9.05 X 9.92,13.0 X 16.0	49.00
	120.0	780.0	7.5 X 7.0	5.42	13.38 X 8.73,13.0 X 14.0	51.70
Mill No. 03	122.0	673.33	7.0 X 7.5	5.90	12.55 X 8.32,8.0 X 14.0	41.00
Mill No. 04	126.0	773.0	8.0 X 7.5	4.73	13.83 X 10.82, 10.0 X 12.0	38.00

With the increasing use of Jute Geotextile worldwide in combating geotechnical problems without hampering environmental sustainability, and the confidence with which they are being used is also developing amongst engineers, manufacturers and end users is opening new avenues for potential Jute Geotextile. Hence, there is a dire need for quality control in terms of testing and evaluation of Jute Geotextile demanding formulation of new standards for testing. The existing test standards for synthetic Geotextiles for evaluating different end use property parameters are not uniform globally i.e., these test standards vary from country to country. However, in the field of standardization for testing of different properties of Jute Geotextiles there is a paucity of data for formulation of specifications and quality control guidelines. Test standards for synthetic Geotextiles understandably do not exactly apply to JGT. While study is on to develop exclusive test and design standard for JGT, there is need to adopt any of the existing standards for synthetic Geotextiles that cater to the majority of requirements in the interim period. The paper suggests adoption of ASTM standards for testing JGT because of the wide range of test standards available and their credibility.

Procedures to secure NABL accreditation[17]: The testing of the developed JGT samples of different functional categories is followed by respective field trials along with vigilant monitoring process at different sites to evaluate their performance for the purpose of standardization of the same to fulfil the requirement of global acceptance. One of the prime criterion of global recognition of the reports and analysis of the test results of the samples carried out by any laboratory is to get accredited by a statutory certifying body of national or international status following any testing standard like ASTM, CEN etc. Heading in this direction, DJFT, IJT, CU has already undertaken a project under the supervision of National Jute Board (NJB), MoT, GoI alongwith Indian Rubber Manufacturers Research Association (IRMRA), Mumbai, India, as consulting agency to get their geotextile laboratory National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited and is on the verge of getting NABL certified. Laboratory Accreditation provides formal recognition of competent laboratories, thus providing a ready means for customers to find reliable testing and calibration services in order to meet their demands.

Benefits of Accreditation: Formal recognition of competence of a laboratory by an Accreditation body in accordance with international criteria has many advantages: i. Potential increase in business due to enhanced customer confidence and satisfaction. ii. Savings in terms of time and money due to reduction or elimination of the need for re-testing of products. iii. Better control of laboratory operations and feedback to laboratories as to whether they have sound Quality Assurance System and are technically competent. iv. Increase of confidence in Testing / Calibration data and personnel performing work. v. Customers can search and identify the laboratories accredited by NABL for their specific requirements from the Directory of Accredited Laboratories. vi. Users of accredited laboratories will enjoy greater access for their products, in both domestic and international markets, when tested by accredited laboratories.

The laboratories seeking accreditation are assessed in accordance with ISO/IEC 17025:2005 for testing and calibration laboratories. A laboratory wishing to be accredited by NABL must have a Quality Manual on its Quality System satisfying the requirements as described in various clauses of ISO/IEC 17025 or ISO 15189 standard. Quality System documentation and its implementation by the laboratories shall be verified by the Assessors for its compliance in accordance with ISO/IEC 17025 or ISO 15189 standard. The laboratory management shall demonstrate to the NABL Assessment Team that all requirements as laid down in the ISO/IEC 17025/ISO 15189 standard, Specific Criteria and other Guidelines / Requirements of NABL are being followed. All applications for accreditation shall have to be in accordance with ISO/IEC 17025 or ISO 15189 Standard

Process of Accreditation: Stage I: i. To prepare the laboratory's application for NABL accreditation, giving all desired information and enlisting the test(s) / calibration(s) along with range and measurement uncertainty for which the laboratory has the competence to perform. Laboratory can apply either for all or part of their testing / calibration facilities. ii. Laboratory has to take special care in filling the scope of accreditation for which the laboratory wishes to apply. In case, the laboratory finds any clause (in part or full) not applicable to the laboratory, it shall furnish the reasons. iii. Laboratories are required to submit three sets of duly filled in application forms for each field of testing / calibration along with two sets of Quality Manual and Application Fees. iv. NABL Secretariat on receipt of application will issue acknowledgement to the laboratory. After scrutiny of application for it being complete in all respects, a unique Customer Registration Number will be allocated to laboratory for further processing of application.

NABL Secretariat shall then nominate a Lead Assessor for giving Adequacy Report on the Quality Manual / Application submitted by the laboratory. A copy of Adequacy Report by Lead Assessor will be provided to Laboratory for taking necessary corrective action, if any. The laboratory shall submit Corrective Action Report

After satisfactory corrective action by the laboratory, a Pre-Assessment audit of the laboratory will be organised by NABL. Laboratories must ensure their preparedness by carrying out its internal audit before Pre-Assessment.

Stage II: i. NABL Secretariat shall organise the Pre-Assessment audit, which shall normally be carried by Lead Assessor at the laboratory sites. ii. The pre-assessment helps the laboratory to be better prepared for the Final Assessment. It also helps the Lead Assessor to assess the preparedness of the laboratory to undergo Final Assessment apart from Technical Assessor (s) and Total Assessment Man-days required vis-à-vis the scope of accreditation as per application submitted by the laboratory. iii. A copy of Pre-Assessment Report will be provided to Laboratory for taking necessary corrective action on the concerns raised during audit, if any. iv. The laboratory shall submit Corrective Action Report to NABL Secretariat. v. After laboratory confirms the completion of corrective actions, Final Assessment of the laboratory shall be organised by NABL.

Stage III: i. NABL Secretariat shall organise the Final Assessment at the laboratory site (s) for its compliance to NABL Criteria and for that purpose appoint an assessment team. ii. The Assessment Team shall comprise of a Lead Assessor and other Technical Assessor (s) in the relevant fields depending upon the scope to be assessed. iii. Assessors shall raise the Non-Conformance (s), if any, and provide it to the laboratory in prescribed format so that it gets the opportunity to close as many Non-Conformance (s) as they can before closing meeting of the Assessment. The Lead Assessor will provide a copy of consolidated report of the assessment to the laboratory and send the original copy to NABL Secretariat.

Laboratory shall take necessary corrective action on the remaining Non-Conformance (s) / other concerns and shall submit a report to NABL within a maximum period of 2 months.

Stage IV: i. After satisfactory corrective action by the laboratory, the Accreditation Committee examines the findings of the Assessment Team and recommend additional corrective action, if any, by the laboratory. ii. Accreditation Committee determines whether the recommendations in the assessment report is consistent with NABL requirements as well as commensurate with the claims made by the laboratory in its application. iii. Laboratory shall have to take corrective action on any concerns raised by the Accreditation Committee. iv. Accreditation Committee shall make the appropriate recommendations regarding accreditation of a laboratory to NABL Secretariat. v. Laboratories are free to appeal against the findings of assessment or decision on accreditation by writing to the Director, NABL. Whenever possible NABL will depute its own technical personnel to be present at the time of assessment as Coordinator and NABL Observer. Sometimes, NABL may at its own cost depute a newly trained Technical Assessor as "Observer" subject to convenience of the laboratory to be accessed.

The testing of all the above said woven jute fabric samples produced and supplied by the different Jute Mills have been carried out in the Geotextile Laboratory of DJFT, IJT, CU as per the test methods sufficed in table-11.

The property parameters of the woven jute fabric samples produced and supplied by the different Jute Mills have been tested in the Geotextile Laboratory of DJFT, IJT, CU and the particulars are provided in table-12.

Table-11
Details of National /International Standards followed for Testing of Geotextile Samples

No.	Test Parameters	ASTM	ISO	BIS
01.	Mass per unit area	D –5261-92	9864	
02.	Nominal Thickness of Geosynthetics	D -5199	9863-1	
03.	Ends/dm and Picks / dm			BIS 1963-1981
04.	Tensile Properties of Geotextiles by the Wide-Width Strip Method	D-4595-86	10319	
05.	Index Puncture Resistance	D - 4833 (96)		
06.	Bursting Strength-Hydraulic / Mullen Bursting Strength	D –3886 / D –3786		
07.	Apparent Opening Size	D-4751–99a	12956	
08.	Flow Rate (l/m^2/sec), Permittivity (/sec) and Permeability (cm/sec) at 50 mm. Constant Water Head Pressure.	D -4491	11058	

Table-12
Testing parameters for woven and open weave JGT samples for application on rural road construction and soil erosion control

Testing Parameters	Woven JGT	Open Weave JGT
Construction : Design of Weave	√	√
Converted Mass: gsm (at 20% M.R.)	√	√
Ends / dm and Picks / dm	√	√
Thickness (mm)	√	√
Wide – width Tensile strength (kN/m) (Warp X Weft) Elongation at Break (%) (Warp X Weft)	√ √	√ √
Index Puncture Resistance (kN)	√	×
Bursting Strength (kg/cm^2)	√	×
Flow Rate (l/m^2/sec) at 50 mm. Constant Water Head Pressure.	√	×
Permittivity (/sec) at 50 mm. Constant Water Head Pressure.	√	×
Permeability (cm/sec) at 50 mm. Constant Water Head Pressure.	√	×
Apparent Opening Size (micron), O_{95}	√	×
Open Area (%)	×	√
Width (cm)	×	√

√- testing of the parameter carried out; ×- testing of the parameter not carried out

Observation and Analysis of the Test Results: During testing of the woven jute fabric samples, produced and supplied by the different Jute Mills in the laboratory, it has been observed that majority of their test resultswere in non-compliance with the specified property parameters that have been supplied to the Mills by NJB, the Project Executing Agency (PEA).

Values of all the dimensional and geotechnical (physical, mechanical and hydraulic properties etc.) property parameters obtained for all the jute woven fabric samples produced in this work by varying process parameters and machine parameters are compared by the method of Simple Average Weighted Ranking Procedure (SAWRP) for the categories 600 – 650 gsm, 650 – 700 gsm, 700 – 750 gsm, 750-800 gsm of such woven JGT fabric samples separately foroptimization of different fabric property parameters. It has been observed from the ranking method that by optimizing mechanical, hydraulic and fabric area density (gsm) properties JGT sample having area density 626.44 gsm (referring table 3) was found to be the best amongst the other fabric samples in the gsm category 600-650 both in terms of its test results, particularly in tensile and porometry properties, as well as cost-effective since its gsm was found to be in well compliance with its gsm category.Similarly, it has been also observed for JGT sample having area density 724 gsm (referring table 4) in the gsm category 700-750 that the sample depicts optimum test results of its property parameters best fitting to the end use requirements alongwith comparatively lower gsm, nearing the lower value of its gsm category thereby proving its economic benefit. Hence, the above stated two samples have been standardized for the application in roads as underlay for strengthening of sub-grades.A similar ranking method had been applied for comparing the values of all the dimensional and geotechnical (physical, mechanical and porometryetc.) property parameters obtained for all the open weave JGT samples. It has been observed from the ranking method that the fabric samples having area densities 482.22, 606.00 and 699.00 belonging to the gsm categories 450-550 gsm, 550-650 gsm and 650-750 gsm respectively

were found to be the best amongst all of the other soil saver samples in terms of their mechanical, porometry and fabric area density (gsm) properties. The reason for their optimization and selection can be accounted for their optimal test values, particularly in tensile and porometry properties, as well as in cost-effectiveness best fitting to the end use requirements alongwith comparatively lower gsm, nearing the mid value of their gsm category thereby proving their economic benefit too. But the test results and their analysis of the other JGT samples were found to be in disagreement with the prescribed specification of the PEA.

The probable causes for such non-amenability of the required property parameters with the prescribed specification may be cited for the reason that for natural fibres like jute, moisture has an important role in deciding many physical properties like area density (gsm), tensile properties and hydraulic properties etc. As per the specified standard, the Mills were asked to supply the different fabric weight samples considering 20% moisture regain (MR). But there was a wide variation found during testing of all those supplied samples and this effect will influence so many property parameters during application as well as after application. After testing it has been found that many samples were not belonging in the range of specified gsm after converting the gsm at 20% moisture regain (MR). Therefore, during calculation of area density (gsm), moisture of the fabric must be measured and to be mentioned accordingly. Moreover the amount of M.R. of the JGT sample should be kept as per standard / requirement. It is also found that the specified thread density (Ends/dm and Picks/dm) for the DW Woven Fabric is too much varied whereas for the Open Weave JGT is within the specified range. Too much variation in spacing of threads (Reed Marking) for DW plain weave samples causes wide variation in flow rate (permittivity) along with Apparent Opening Size (AOS) in the JGT fabric which is not at all recommended. Instead of double yarns taken through the mail eyes during preparation of DW Plain Weave fabric, sometimes single end has been taken, which causes faulty fabrics as well as low tensile properties in the Machine Direction (MD), i.e., warp way. This also affects overall assistance of warp yarns, which causes variation of other property of the fabrics. The tensile strength of both the Woven JGT and Open Weave JGT are not in tune with the specified tensile strength. In most of the cases the tensile strength is on the lower side than the specified standards. After proper investigation through different testing of warp and weft yarns it has been found that there is no gross variation of warp count (pounds/spyndle) whereas there is a wide variation of the weft count (pounds/spyndle) as well as batch variation, which causes areasonable variation of the tensile properties of the produced JGT fabrics. Such wide variations found in the test results of the prime property parameters of almost all of the woven JGT samples, produced and supplied by the different Jute Mills, proved to be a major deterrent on the way of acceptance of the samples. In this direction, it had been thought to determine the Tolerance Limits of the important property parameters of the JGT samples, with the help of proper statistical methods so that the JGTsamples with variable property parameters falling within this determined tolerance limit can be accepted. To elucidate this matter certain prime particular property parameters such as area density (gsm), bursting strength, open area percentage, values of onesuch woven Jute Geotextile sample and one open weave soil saver sample had been selected for demonstration of their tolerance limits.

Determination of the Tolerance Limit of the manufactured JGT samples: It is worthy to mention here that due to wide variations of fibre properties as well as process variabilities it is very difficult to reproduce exact JGT fabrics as per predetermined specifications for geotechnical end-uses. Therefore, from the global standardization point of view of the JGT samples, determination of such tolerance limit for different important property parameters proved to be a very important feature. Therefore, for calculation of the tolerance limit, for the above stated parameters of the developed JGT samples, the below explained method was adopted. Usually all population values are not available that is why we have taken samples and express Standard Error (S.E.) as Standard Deviation (S.D.) $/\sqrt{n}$, where n is the population size. In this case we take a sample and calculated the S.D. of the same sample. As per Statistical calculation Standard Error (S.E.) of Mean will be S.D. $/\sqrt{n}$. The average value of the determined property parameters of the fabric samples produced by the different Jute Mills has been tabulated in tables 13, 15, 17, 19, 21. The S.D. of the samples have been determined, using the following mathematical correlation-S.D. = $\sqrt{\sum(x-\bar{x})^2/(n-1)}$ where $(x-\bar{x})$ = Deviation of the observation from the Specified value and the values have been depicted in tables 14, 16, 18, 20, 22.

Table-13

Area density (gsm) values of the woven JGT samples produced by the different Jute Mills

Fabric Wt. (gsm)	642.66	626.44	632.20	612.00	605.00	634.00	614.00	618.00	640.34	615.50
Jute Mills	1	2	3	4	5	6	7	8	9	10

Table-14

Different gsm values and calculation of S.D.

SI. No.	x	$\bar{x}$	$x-\bar{x}$	$(x-\bar{x})^2$	
1.	642.66	624.12	18.59	343.73	S.D.= $\sqrt{\Sigma(x-\bar{x})^2/(n-1)}$ = 12.81
2.	626.44		2.32	5.38	
3.	632.20		7.08	50.12	
4.	612.00		-12.12	146.89	
5.	605.00		-19.12	365.57	
6.	634.00		9.88	96.82	
7.	614.00		-9.62	92.54	
8.	618.00		-5.52	30.47	
9.	640.34		16.22	263.80	
10.	615.50		-9.12	84.27	

Standard Error (S.E.) = S.D. / $\sqrt{\mathbf{n}}$ = 4.05, t = Nominal Mean — Sample Mean / S.E. for degree of freedom, v = n-l = 9, t = 2.262 at 5% significant level (obtained from table of significant limit, “t” has sampling distribution of its own which is not regular). Nominal Mean = Sample Mean ± t × S.E., i.e., Nominal Mean = 627 ± 2.262 × 4.05 = 627 ± 9.16.Nominal Mean = Sample Mean ± 1.5 %.Considering Normal Distribution of Sample, Nominal Mean = 627 ± 1.96 × 12.81, Nominal Mean = Sample Mean ± 4.0%.

Table-15
Bursting Strength values of the JGT samples produced by the different Jute Mills

Bursting Strength (kg/cm^2)	28.07	27.75	24.46	23.10	28.30	25.68	26.20	28.00	25.15	24.40
Jute Mills	1	2	3	4	5	6	7	8	9	10

Table-16
Different Bursting Strength values and calculation of S.D.

SI No.	x	$\bar{x}$	$x-\bar{x}$	$(x-\bar{x})^2$	
1.	28.07		1.96	3.84	
2.	27.75		1.64	2.69	
3.	24.46		-1.65	2.72	
4.	23.10		-3.01	9.06	
5.	28.30	26.11	2.19	4.79	S.D.= $\sqrt{\Sigma(x-\bar{x})^2 / (n-1)}$ = 0.62
6.	25.68		-0.43	0.18	
7.	26.20		0.09	0.0008	
8.	28.00		1.89	3.57	
9.	25.15		-0.96	0.92	
10.	24.40		-1.71	2.92	

t = Nominal Mean — Sample Mean / S.E. For degree of freedom, v = n-l = 9, t = 2.262 at 5% significant level (obtained from table of significant limit, t has sampling distribution of its own which is not regular). Nominal Mean = Sample Mean ± t × S.E., = 627 ± 2.262 × 0.196. Nominal Mean = Sample Mean ± 0.07 %. Considering Normal Distribution of Sample, Nominal Mean = Sample Mean ± 1.96 × 0.62 = 627 ± 1.22 .Nominal Mean = Sample Mean ± 0.19 %.

Table-17
Apparent opening size values of the JGT samples produced by the different Jute Mills

AOS(O_{95}) micron	280	500	460	520	720	385	770	450	500	760
Jute Mills	1	2	3	4	5	6	7	8	9	10

Table-18
Different Apparent opening size values and calculation of S.D.

SI No.	x	$\bar{x}$	$x-\bar{x}$	$(x-\bar{x})^2$	
1.	280		-254.5	64770.25	
2.	500		-34.5	1190.25	
3.	460		-74.5	5550.25	
4.	520		-14.5	210.25	
5.	720		185.5	34410.25	S.D.= $\sqrt{\Sigma(x-\bar{x})^2 / (n-1)}$ =54.79
6.	385	534.5	-149.5	22350.25	
7.	770		235.5	55460.25	
8.	450		-84.5	7140.25	
9.	500		-34.5	1190.25	
10.	760		225.5	50850.25	

t = Nominal Mean — Sample Mean / S.E. For degree of freedom, v = n-l = 9, t = 2.262 at 5% significant level (obtained from table of significant limit, t has sampling distribution of its own which is not regular). Nominal Mean = Sample Mean ± t × S.E., = 627 ± 2.262 ×17.34. Nominal Mean = Sample Mean ± 6.26 %. Considering Normal Distribution of Sample, Nominal Mean = Sample Mean ± 1.96 ×54.79 = 627 ± 107.39. Nominal Mean = Sample Mean ± 17.13%.

Table-19
Area density (gsm) values of the open weave JGT samples produced by the different Jute Mills

Fabric Wt. (gsm)	467.00	482.22	536.00	558.00	627.55	583.00	495.70	512.30	500.08	521.00
Jute Mills	1	2	3	4	5	6	7	8	9	10

Table-20
Different gsm values and calculation of S.D.

SI No.	x	$\bar{x}$	$x-\bar{x}$	$(x-\bar{x})^2$	
1.	467.00	528.29	-61.29	3756.46	S.D.= $\sqrt{\Sigma(x-\bar{x})^2 / (n-1)}$ = 16.42
2.	482.22		-46.07	2122.44	
3.	536.00		07.71	59.44	
4.	558.00		29.71	882.68	
5.	627.55		99.26	9852.55	
6.	583.00		54.71	2993.18	
7.	495.70		-32.59	1062.11	
8.	512.30		-15.99	255.68	
9.	500.08		-28.21	795.80	
10.	521.00		-07.29	53.14	

Standard Error (S.E.) = (S.D. / $\sqrt{n}$) = 5.20, t = Nominal Mean — Sample Mean / S.E. For degree of freedom, v = n-l = 9, t = 2.262 at 5% significant level (obtained from table of significant limit, t has sampling distribution of its own which is not regular). Nominal Mean = Sample Mean ± t × S.E. Nominal Mean = 500 ± 2.262 × 5.20, 500 ± 11.76, Nominal Mean = Sample Mean ± 2.35%. Considering Normal Distribution of Sample, Nominal Mean = Sample Mean ± 1.96 × **б,** 500 ± 1.96 × 16.42, 500 ± 32.18, Nominal Mean = Sample Mean ± 6.44%.

Table-21
Open Area Percentage values of the open weave JGT samples produced by the different Jute Mills

Open Area (%)	51.11	55.87	51.10	51.32	51.00	47.50	50.50	49.60	47.00	48.60
Jute Mills	1	2	3	4	5	6	7	8	9	10

Table-22
Different Open Area Percentage values and calculation of S.D.

SI No.	x	$\bar{x}$	$x-\bar{x}$	$(x-\bar{x})^2$	
1.	51.11	50.36	0.75	0.56	S.D.= $\sqrt{\Sigma(x-\bar{x})^2 / (n-1)}$ = 0.83
2.	55.87		5.51	30.36	
3.	51.10		0.74	0.55	
4.	51.32		0.96	0.92	
5.	51.00		0.64	0.41	
6.	47.50		-2.86	8.18	
7.	50.50		0.14	0.02	
8.	49.60		-0.76	0.58	
9.	47.00		-3.36	11.29	
10.	48.60		-1.76	3.09	

Standard Error (S.E.) = (S.D. / $\sqrt{n}$) = 0.26, t = Nominal Mean — Sample Mean / S.E. For degree of freedom, v = n-l = 9, t = 2.262 at 5% significant level (obtained from table of significant limit, t has sampling distribution of its own which is not regular). Nominal Mean = Sample Mean ± t × S.E., 500 ± 2.262 × 0.26, 500 ± 0.59. Nominal Mean = Sample Mean ± 0.12%. Considering Normal Distribution of Sample, Nominal Mean = Sample Mean ± 1.96 × **б,** 500 ± 1.96 × 0.83, 500 ± 1.63, Nominal Mean = Sample Mean ± 0.33 %.

Conclusion

Amongst all of the Jute Geotextile samples produced and supplied by the different Jute Mills and tested in the Geotextile Laboratory, DJFT, IJT, CU it has been observed thatdouble warp (DW) plain weave JGT fabric samples, with a gsm range of 600-900 and open weave JGT (soil saver) samples in the gsm range of 450-750 have shown cost effectiveness, techno-economic viability, dimensional stability and improved mechanical properties alongwith greater cover factor ensuring restricted number of materials to pass through across its plane. Therefore, from design and engineering point of view the above said JGT fabric samples ensured themselves as a suitable and potential geotextile fabric as per end-use requirements. The mechanical and hydraulic properties of the produced fabric samples, within the mentioned gsm ranges, are found to be in well concurrent with the requirements of rural road pavement construction, river bank protection as well as in hill slope protection. The JGT samples showing area density higher than 900 gsm in the case of woven samples and 750 gsm for soil savers are found to be enhancing the overall cost factor including raw material cost (batch cost). After developing such jute woven geotextiles (JGT) they have been applied for several field trial applications in the areas of rural road construction, river bank protection alongwith hill slope protection in India and Bangladesh simultaneously. For evaluation of the performance of such woven JGT samples constant monitoring work is in progress and the primary report is quite encouraging and promising followed by a long-term monitoring process.

In order to make the Geotextile Laboratory, Department of Jute and Fibre Technology, University of Calcutta, India imperative both at national and international level of competence the Department has already undertaken a project under the supervision of National Jute Board (NJB), MoT, GoI alongwith Indian Rubber Manufacturers Research Association (IRMRA), Mumbai, India, as consulting agency to get their geotextile laboratory **National Accreditation Board for Testing and Calibration Laboratories (NABL)** accredited and is on the verge of getting NABL certified.

As the next step for commercialization, the national as well as global standards for those fabric specimens in terms of their dimensions, properties and performance levels are needed to be established. In this direction, the crucial work of achieving standards with tolerance limits had been worked out statistically which had been explained in this paper.

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