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Potential Applications of Open Weave Jute Geotextile (Soil Saver) in Meeting Geotechnical Difficulties

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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. Out of the several natural agents causing extensive damages to roads, landslides can claim to be a major destroyer. Open weave Jute Geotextile (JGT), popularly known as soil savers, if properly designed can fulfil the said criteria besides facilitating growth of vegetation. This article delineates testing and analysis of the prime property parameters of some open weave JGT samples of different fabric weight categories, manufactured in the jute mills, followed by their comparative analysis based on which they have been selected to fulfil the end-use requirement. This was followed by determination of the tolerance limit of the property parameters of the selected open weave JGT samples by statistical interpretation for formulation of the specification before the actual field trial.

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Keywords: Jute; natural fibres; geotextiles; jute geotextiles; soil savers; fabric weight.

1. Introduction

The phenomenon of landslips and hill slope management has been under intensive study by geologists and geotechnical engineers [1]. Their thorough research reveals that landslides occur in different forms considering the nature of mass movements like that of earth, rocks and debris alongwith type of materials moved [2]. Case studies carried out at different hill slopes across the world show that severe and uncontrolled surficial erosion is the major triggering factor behind landslips [3]. Precipitation is the principal agent of such surficial erosion of hill slopes [4]. Kinetic energy of rain drops dissociates the top soil. The extent of such erosion depends on the intensity of precipitation, erodibility of soil covering the hill slope, the hill slope that influences the velocity of surface run-off

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and migration of detached soil particles. Deforestation is considered as the major contributing factor to erosion [5]. The detached soil particles and debris are carried by the run-off and get deposited at the slope-bottom foothill choking the natural drainage. The present global trend to combat soil erosion in all types of soil is to go in for bio-engineering measures which are essentially nature's involvement in controlling landslips. Open weave JGT manufactured from jute rove and having a three-dimensional structure, when laid on the slope surface initially gives protection against soil disintegration due to rain splash as a partial soil cover [6].

Open weave JGT has got triple advantages. Firstly, its weft yarns pose successive hurdles on the path of the sheet flow and will thus reduce the flow velocity at every crossing on its way down the slope. Secondly, the pores of the fabric will help better water absorption due to temporary stagnation of water within the pore spaces. Lastly, growth of vegetation will be more lucid if there are openings in the fabric. Keeping in mind about reduction of the velocity of the run-off at an optimum level and the extent to which jute yarn bundles in open weave JGT can withstand a certain velocity of surface run-off considering its extensibility and tensile strength for a specified opening as per the end-use requirements, design methodology of the open weave JGT has been framed and subsequently asked the various Jute Mills to manufacture the fabric samples. The open weave JGT samples, produced and supplied by the different Jute Mills, have been tested and analysed by the Geotextile Laboratory, Department of Jute and Fibre Technology, University of Calcutta. The comparative analysis of the results of different tests carried out with the produced JGT samples has been performed based on which three different open weave JGT soil savers of different area densities measured have been optimized and selected. This was followed by determination of the tolerance limit of the prime property parameters of the optimized and selected open weave JGT samples by statistical interpretation for formulation of the specification before the actual field trial in the field of hill slope management.

Nomenclature

JGT	jute geotextile
GSM	gram per square meters
AWRP	Average Weighted Ranking Procedure

1.2 Results and Conclusions

As per the plan of the work, nine numbers of open weave JGT samples having three fabric weight ranges, viz., 450 -550 gsm, 550 – 650 gsm and 650 – 750 gsm have been produced from a commercial Jute Mill. The test results are shown in tables 1 (a to c) respectively.

Table 1(a). Physical, mechanical and porometry properties of the open weave JGT samples within the gsm range 450-550.

Parameters → / Sample No. ↓	Physical Property				Mechanical and Porometry Properties		
	Width (cm)	Converted Mass @ 20% moisture regain	Ends /dm × Picks/dm	Thickness (mm)	Tensile Strength (kN/m), [Warp × Weft]	Elongation (%) [Warp × Weft]	Open Area (%)
01.	122.0	467.00	7.0 × 5.0	3.81	7.00 × 4.66	10.0 × 8.0	51.11
02.	122.0	482.22	7.0 × 5.0	4.62	6.34 × 5.74	11.0 ×12.0	55.87
03.	122.0	536.00	7.0 × 5.0	4.96	4.85 × 5.55	16.0 × 16.0	51.10

Table 1(b). Physical, mechanical and porometry properties of the open weave JGT samples within the gsm range 550-650.

Parameters → / Sample No. ↓	Physical Property				Mechanical and Porometry Properties		
	Width (cm)	Converted Mass @ 20% moisture regain(M.R.)	Ends /dm × Picks /dm	Thickness (mm)	Tensile Strength (kN/m), [Warp × Weft]	Elongation (%) [Warp × Weft]	Open Area (%)

04.	122.0	593.11	8.0 × 7.0	5.47	11.76 × 6.19	7.0 × 12.0	48.00
05.	122.0	606.00	7.5 × 6.5	4.52	9.23 × 6.00	10.0 × 10.0	51.50
06.	122.0	633.00	8.0 × 6.5	4.69	14.07 × 8.37	9.0 × 11.0	41.00

Table 1(c). Physical, mechanical and porometry properties of the open weave JGT samples within the gsm range 650-750.

Parameters → Sample No. ↓	Physical Property				Mechanical and Porometry Properties		
	Width (cm)	Converted Mass @ 20% moisture regain(M.R.)	Ends /dm × Picks /dm	Thickness (mm)	Tensile Strength (kN/m), [Warp × Weft]	Elongation (%) [Warp × Weft]	Open Area (%)
07.	122.0	699.00	7.5 X 8.0	4.66	16.86 × 9.98	9.0 × 10.0	41.50
08.	122.0	713.30	8.0 X 8.0	5.30	14.38 × 6.98	8.0 × 13.0	40.30
09.	122.0	660.00	7.5 X 7.5	5.47	9.05 × 9.92	13.0 ×16.0	49.00

Values of all the dimensional and geotechnical (physical, mechanical and porometry properties etc.) property parameters obtained for all the open weave JGT samples produced in this work have been compared by the method of simple Average Weighted Ranking Procedure (AWRP) for three categories (450 – 550 gsm, 550 – 650 gsm and 650 – 750 gsm) of such JGT samples separately for optimization of different fabric property parameters. For ranking within the specified range of fabric area density, each property parameter of each sample is proportionately weighted as compared to the best values obtained in that property parameter to award ten (10) point and rest of the obtained values lower than the best value were weighted proportionately. Finally, considering all the property parameters together simple average were determined to get the rank within that class and shown in Tables 2 (a to c) (provided in annexure-1). It has been observed from the ranking method that by optimizing mechanical, porometry and fabric area density (gsm) properties the fabric sample no. 1 within gsm range 450 – 550, sample no. 6 within gsm range 550 – 650 and sample no. 7 within gsm range 650 – 750 have secured the highest rank mainly due to their higher gsm property parameters. But considering the techno-economic aspect such a fabric was desperately needed to be selected which would confirm with the optimum condition as per the design as well as end use requirements with its satisfactory test results during its period of performance. Therefore, keeping techno-economic viability in mind, sample no. 2 in Table 1(a) was found to be the best amongst the other fabric samples in the gsm category 450 – 550 both in terms of its optimal test values, particularly in tensile and porometry properties, as well as cost-effectiveness since its gsm was found to be lying near the mid value of its gsm category. Similarly, it has been also observed for sample no.5 in Table 1(b) lying in the gsm category 550 – 650 that the sample depicts optimum test results of its property parameters best fitting to the end use requirements along with comparatively lower gsm, nearing the mid value of its gsm category thereby proving its economic benefit. Almost the same picture has been obtained for sample no. 7 in Table 1(c) lying in the gsm category 650 – 750. After selection of the three fabric samples of gsm 482.22, 606.00 and 699.00 respectively, their test results have been placed before the relevant Fabric Design and Engineering Committee, entrusted under the purview of this work, to furnish a full-scale specification to the different Jute Mills of West Bengal, India as well as in Bangladesh for the purpose of manufacturing of the several open weave JGT samples as per the mentioned specifications, provided in Table 3 for carrying out different field trial applications in hill slope management.

Table 3. Full-scale specifications of the open weave JGT samples identified for field trial.

Construction	Open weave jute soil saver for hill slope management		
Width (cm) Minimum	122 cm (± 5%)		
Tensile strength (kN/m) (Warp way × Weft way)	6.5 (+4%, -2%) 4.5(+4%, -2%)	8 (+4%, -2%) 7 (+4%, -2%)	8 (+4%, -2%) 8 (+4%, -2%)
Untreated Fabric weight (gsm)	500 (± 10%) (with thicker weft & thinner warp yarn)	600 (± 10%)	700 (± 10%)
Ends × Picks / dm	6.5 (+4, -2) x 4.5 (+2, -1)	7 (+4, -2) x 6 (+2, -1)	7 (+4, -2) x 7 (+2, -1)
Thickness (mm)	4.50 (± 10%)	5.25 (± 10%)	5.50 (± 10%)
Elongation at break (%) Minimum (Warp way × Weft way)	≤10 x 12	≤ 10 x 10	≤ 9 x 10
Open Area Percentage	50-65	45-50	40-45
Water Holding Capacity(%) on dry wt.	450-500	450-500	550-600

Tolerance limits of the important property parameters of the open weave JGT samples (as shown in Table 4) which have been identified for the hill slope protection were calculated based on Standard Statistical Method which has been discussed hereby. The reason for determination of Tolerance Limits of the important property parameters like area density, tensile strength, porometry etc. of the open weave JGT samples may be attributed to the fact that the average values of these property parameters of the JGT samples so obtained from the different Jute Mills after testing, do not agree perfectly with the specified value which is quite natural and a regular phenomenon. Therefore, a tolerance limit has been statistically determined by which the samples with variable property parameters falling within this determined tolerance limit (as shown in Table 5) can be accepted. To elucidate this matter two numbers of prime particular property parameters such as gsm, and open area values of the open weave JGT samples had been chosen for demonstration of their tolerance limits.

Table 4. gsm values of the open weave JGT samples (450-550 gsm) 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 5. Different gsm values and calculation of S.D.

No.	x	$\bar{x}$	$x-\bar{x}$	$(x-\bar{x})^2$	
1.	467.00		-61.29	3756.46	
2.	482.22		-46.07	2122.44	
3.	536.00		07.71	59.44	$S.D. = \sqrt{\Sigma(x-\bar{x})^2 / (n-1)}$
4.	558.00		29.71	882.68	= 16.42
5.	627.55	528.29	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	

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Appendix A

Table 2(a). Ranking of Fabric Samples in gsm range 450 to 550.

Sample No.	gsm	Ends/ dm	Picks/ dm	Thickness (mm)	Tensile Strength in Warp (kN/m)	Rank	Tensile Strength in Weft (kN/m)	Rank
01.	467.00	7.00	5.00	3.81	7.00	10.00	4.66	8.11
02.	482.22	7.00	5.00	4.62	6.34	9.85	5.74	10.00
03.	536.00	7.00	5.00	4.96	4.85	6.92	5.55	9.66

Table 2(a). Ranking of Fabric Samples in gsm range 450 to 550 (Continuation)

Sample No.	Elongation in Warp (%)	Rank	Elongation in Weft (%)	Rank	Open Area (%)	Rank	Total Rank	Average Rank
01.	10.00	10.00	8.00	10.00	51.11	9.99	48.10	9.62
02.	11.00	9.09	12.00	6.66	55.87	9.14	44.74	8.94
03.	16.00	6.24	16.00	5.00	51.10	10.00	37.82	7.56

Table 2(b). Ranking of Fabric Samples in gsm range 550 to 650.

Sample No.	gsm	Ends/ dm	Picks/ dm	Thickness (mm)	Tensile Strength in Warp (kN/m)	Rank	Tensile Strength in Weft (kN/m)	Rank
04.	593.11	8.00	7.00	5.47	11.76	8.35	6.19	7.39
05.	606.00	7.50	6.50	4.52	9.23	6.56	6.00	7.16
06.	633.00	8.00	6.50	4.69	14.07	10.00	8.37	10.00

Table 2(b). Ranking of Fabric Samples in gsm range 550 to 650 (Continuation).

Sample No.	Elongation in Warp (%)	Rank	Elongation in Weft (%)	Rank	Open Area (%)	Rank	Total Rank	Average Rank
04.	7.00	10.00	12.00	8.33	48.00	8.54	42.61	8.52
05.	10.00	7.00	10.00	10.00	51.50	7.96	38.68	7.73
06.	9.00	7.70	11.00	9.09	41.00	10.00	46.79	9.35

Table 2(c). Ranking of Fabric Samples in gsm range 650 to 750.

Sample No.	gsm	Ends/ dm	Picks/ dm	Thickness (mm)	Tensile Strength in Warp (kN/m)	Rank	Tensile Strength in Weft (kN/m)	Rank
07.	699.00	7.50	8.00	4.66	16.86	10.00	9.98	10.00
08.	713.30	8.00	8.00	5.30	14.38	8.52	6.98	6.99
09.	660.00	7.50	7.50	5.47	9.05	5.36	9.92	9.93

Table 2(c). Ranking of Fabric Samples in gsm range 650 to 750 (Continuation).

Sample No.	Elongation in Warp (%)	Rank	Elongation in Weft (%)	Rank	Open Area (%)	Rank	Total Rank	Average Rank
07.	9.00	8.88	10.00	10.00	41.50	9.71	48.59	9.71
08.	8.00	10.00	13.00	7.69	40.30	10.00	43.20	8.64
09.	13.00	6.15	16.00	6.25	49.00	8.22	35.91	7.18

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