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Geosynthetics and geonatural composites in filter application

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ABSTRACT: A brief account of potential use of geocomposites, made from a combination of geosynthetics and geonaturals, is presented. Test results on five grades of geocomposite are presented with emphasis on application in filtration. The geonaturals are mainly intended for enduring the high initial stresses during construction. In some cases these may also act as construction expedient without impairing the primary function of the geosynthetics, in the short run as well as in the long run. Special emphasis is given on the use of geocomposites as filter layers in erosion control involving under water placement and sinking. Feasibility on use of these materials as geobags or geotubes is also reported. Promising results are obtained.

1 INTRODUCTION

After the advent of geosynthetics around three decades ago, most of the research and applications of geonaturals, especially jute, was directed towards developing these materials as alternative to geosynthetics. Due to their biodegradability and hence short life, most target use areas were those where the life of the application is short. Examples are use as soil saver for supporting vegetation growth (Shahid 1994) and vertical drains (Lee et. al. 1989), where the effective life ends with vegetation growth and consolidation of soil layers. The author envisaged the use of geonaturals, mainly jute, as complementary companion of geosynethics, rather than a replacement.

Geocomposites are defined here as composites of geosynthetics and geonatural fabrics. The geonatural fabrics may be made of fibres like jute, coconut coir etc. A good combination is woven jute fabric in composite with non woven geosynthetics. While the jute fabric alone may be of very limited use, geocomposites may be used beneficially in a number of applications. Some geocomposites are being developed now which may see application in some pilot projects soon.

Use of geosynthetics and materials of natural origin in composite form, is not entirely a new concept. One of the most widely used methods of underwater sinking and placement of geosynthetics is by using fascine mattresses tied and formed on geosynthetics materials. These are used to facilitate positioning by floatation followed by sinking by dumping stones from barges. In most geosynthetics applications, it may be seen that these are not only required to fulfil the primary design criteria as filters but some secondary criteria are also imposed. These are mainly to survive rigors of constructions such as dumping of large stone in a revetment structure. Mobilization of construction machinery e.g. vibro compactors, may impose loading in excess of the working loads. Jute fabrics and geosynthetics may also be used to produce special types of geocomposite, where a sandwich layer of granular materials or other mineral aggregates may be used. These types of geocomposite will resemble "ProFix" mattresses used in a number of applications. (Tutuarima & van Wijk 1984) The large self weight of this type of geocomposite will facilitate sinking of the whole mattress at desired position under water. On these, revetment structures may be constructed by dumping stones or concrete blocks. Here the jute fabric and the sand sandwich will act as a cushioning layer to protect the geosynthetics from the rigours of dumping.

Geocomposites may also be used to fabricate geobags and geotubes where the geonatural will endure the initial stresses during filling, dumping and placement of these as well as stones and other bags over these.

Schematic diagram showing sand filled geotubes application in embankment slopes is presented in Figure 1. Suitable revetment or cover layer may be placed on these. Figure 2 shows

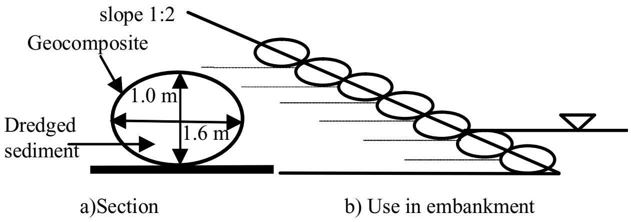

Figure 1. Use of geotubes in embankment

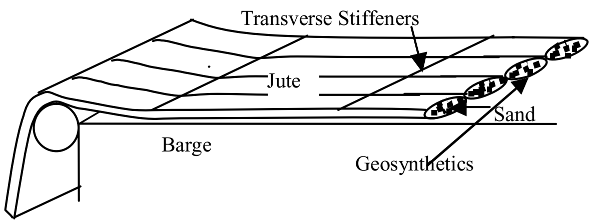

Figure 2 Sand filled geocomposite mattress

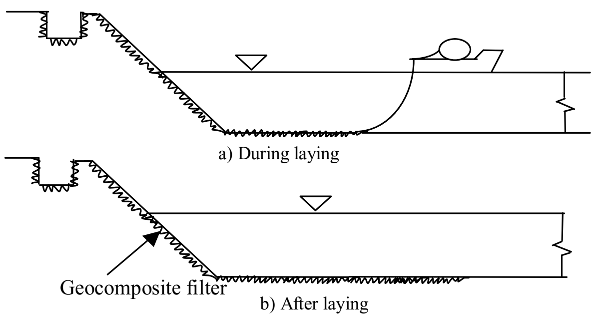

Figure 3. Geocomposite filters for river banks and beds

schematic details of sand filled geocomposite for underwater sinking and the sinking sequence is shown in Figure 3.

Index properties of five grades of geocomposite are presented along with comparisons with the respective geosynthetics component. Test results on feasibility of use of geocomposites for two areas of application are presented. One as filter layers for underwater slopes and beds and the other as geobags and geotubes.

2 AREAS OF APPLICATION AND FUNCTIONS

Geocomposite may be used beneficially in a number of applications where filtration is the dominant function. These may include applications as filter layer on slopes and beds, especially for under water applications, geobags and geotubes and separator and filter layer for unpaved roads. In most of these applications the geonatural may be envisaged to provide a cheap bulk material to protect the geosynthetics from initial stresses imposed by constructional loads, which in cases, may be considerably more than the stresses under operational conditions. In these applications, although the geonaturals will be used to provide strength e.g. tear, puncture and bursting resistance during construction, the geocomposite should also be able to perform the primary function of filtration satisfactorily, during all the phases of functioning. Additionally, the geonatural may provide protection of the geosynthetics from thermal and photo degradation allowing phase construction under exposure conditions and vegetative growth.

Although the mechanical resistance of the geonatural will be large enough to provide the required shielding against constructional stresses there may be some reduction in filter properties like permeability and effective opening size, compared with those for geosynthetics alone. This reduction should be limited to an acceptable value.

In an intended application, the behaviour of a geocomposite should be considered in three phases. These are (i) during construction (ii) during biodegradation of the geonatural and (iii) after biodegradation. During these phases, the geocomposite should be able to retain its integrity without damage, keeping the filter ability of the system to a satisfactory level.

A qualitative diagram showing puncture strength of a typical geocomposite during the three phases of its life is presented in Figure 4. Also presented are the puncture resistance of the geosynthetics and puncture loading during these phases. The contribution of the biodegradable geonatural in resisting puncture loading during construction is shown here. This is in excess of the puncture resistance of the geosynthetics alone. Under initial loading, the geonatural will act as the first line of defense, provided by its bulk, strength and stiffness.

3 CONSTRUCTION OF GEOCOMPOSITES

Geocomposites may be produced from a wide combination of materials possessing diverse structural make up. The individual components of a geocomposite (i.e. geonatural and geosynthetics) should be carefully chosen and constructed to supplement each other to achieve properties demanded by specific end uses. The components may be sewn or needle punched together to produce the geocomposite. In some applications mineral aggregates or clay may be sandwiched between the two components. Compositions of some types of geocomposite are described here. These are, a) woven/ non woven: a woven geonatural may be used with a non woven geosynthetics; b) non woven/ non woven: a non woven geonatural may be used with a non woven geosynthetics and c) non woven/woven. A non woven geonatural may be used with a woven geosynthetics.

In all these cases the geonatural component may be produced from jute, coconut coir, etc. The geocomposite may be produced by needle punching the system with extra fibres in between the components. Moreover special types of geocomposite may be produced by introducing thin layers of mineral aggregates like sands and clays and extra fibers sand witched between the two components and needle punching the whole system. Where thick layers of mineral aggregates are required, small pockets or large longitudinal cells may be produced by sewing the two fabric components of the geocomposite together. Filling of these pockets and cells should normally be carried out on site in a continuous sequence prior to placement.

4 LABORATORY STUDIES

During this initial part of the studies, five grades of geocomposite were constructed from fabrics readily available on the market. The geonaturals were not purpose constructed for the intended applications. These included two grades of non woven/non woven and three grades of woven/non woven geocomposite.

4.1 *Non woven/non woven geocomposites*

Two grades of non woven/non woven geocomposite were constructed. A thin non woven heat bonded geosynthetics was used in both the cases. In one, jute felt was needle punched on the geosynthetics. The jute felt was produced from waste jute from a jute carpet factory. This geocomposite is designated here as GT-Felt. In the other, a non woven coconut coir mattress was stitched to form a sandwich between the non woven geosynthetics and an open mesh light jute fabric. The later was used to retain the geometrical integrity of the coir. This geocomposite is designated here as GT-Coir. Index properties of the two grades of geocomposite are presented in Table 1. Also presented are index properties of the component geosynthetics and geonaturals. For ease of comparison, ratios of the properties with respect to those for geosynthetics alone are also presented.

4.2 *Woven/Non woven geocomposite:*

Three grades of woven/non woven geocomposite were constructed. In all the cases, grades of non woven needle punched polypropylene geosynthetics were needle punched to grades of woven jute fabrics. Extra fibers of jute felt were used in between the two fabrics and the system was needle punched to form the geocomposite. The jute fabrics used bore the product name Canvas, Twill and Soil saver. These grades of geocomposite are designated here as GT-Canvas, GT-Twill and GT-Soil saver. Index properties of grades of geocomposite GT-Canvas and GT-Twill are presented in Table 2 and those of GT-Soil saver in Table 3. Like those in Table 1, index properties of the component geosynethics and geonaturals as well as ratios with respect to those of the geosynthetics alone are also presented in these Tables.

4.3 *Gradient ratio test*

Gradient ratio tests were performed on four grades of geocomposite, GT-Felt, GT-Coir, GT-Twill and GT-Soil saver, to establish their filterability. An overall hydraulic gradient of approximately 2 was maintained in these tests. The soil used was erosion prone sandy silt river sediment, typical of soils in Bangladesh. The soil parameters are; D_{60} = 0.065 mm, C_U = 10 and $k_s = 2.0\text{x}10^{-5}$ m/s. The soil was used in a very soft state having a moisture content of 40 percent, near its liquid limit. The gradient ratio as a function of time for the geocomposite GT-Soil saver is presented in Figure 5. At the end of 100 hours the gradient ratio stabilized to a value around 1.3. A value of gradient ratio GR < 3 is accepted as satisfactory filter performance. Test results for the grades GT-Felt, GT-Coir, GT-Twill also yielded satisfactory results with stabilised GR values of 1.4, 1.7 and 2.2 respectively. Inspection of the downstream faces of the grades of geocomposite, after test, indicated no evidence of piping through

4.4 *Discussion on behaviour*

It should be noted here that primary filtration behaviour on the short run will be dictated by the filterability of the less porous component, forming the geocomposite. These properties are

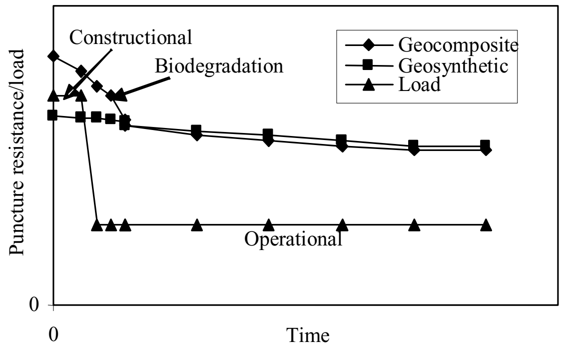

Figure 4. Function of geocomposite in puncture resistance

Table 1: Comparative index properties of geosynthetics, geonatural and geocomposite

Properties	Unit/ Ratio	Geosyn-thetics	Geo-natural	Geocomposite	
		GT*	Jute felt	GT-Felt	GT-Coir
Unit weight	gsm	157	730	889	1123
	Ratio	1	4.6	5.8	7.3
Thickness	mm	1.54	5.0	6.24	11.28
	Ratio	1	3.2	4.1	7.3
Grab	N	569	330	850	850
Tensile Strength	Ratio	1	0.58	1.5	1.5
Grab	%	54	24	51	51
Elongation	Ratio	1	0.44	0.95	0.95
Wide Strip	kN/m	10.5	-	11.6	12.0
Tensile Strength	Ratio	1	-	1.1	1.1
Wide Strip	%	48	-	53	50
Elongation	Ratio	1	-	1.1	1.05
Drop Cone	mm	18.4	9.0	8.1	0
Penetration	Ratio	1	0.5	0.40	0
Trapezoidal Tear	N	124	-	268	250
Strength	Ratio	1	-	2.2	2.0
Burst Strength	kPa	1373	2070	2387	2200
	Ratio	1	1.5	1.7	1.6
Permeability	10^{-3}m/s	2.0	6.8	2.4	6.0
	Ratio	1	3.4	1.2	3

Table 2: Comparative index properties of geosynthetics, geonatural and geocomposite

Properties	Unit/ Ratio	Geosyn thetics	Geonaturals		Geocomposite	
		GT*	Canvas	Twill	GT-Canvas	GT-Twill
Unit weight	gsm	315	550	631	865	946
	Ratio	1	1.75	2	2.75	3
Thickness	mm	3.08	1.25	1.68	4.30	4.36
	Ratio	1	0.41	0.55	1.4	1.42
EOS	mm	0.106	0.210	0.85	0.106	0.106
	Ratio	1	1.98	8.02	1	1
Grab Tensile	N	1130	1140	625	1535	1330
Strength	Ratio	1	1.01	0.55	1.36	1.18
Grab	%	190	55	12	30	20
Elongation	Ratio	1	0.29	0.06	0.16	0.11
Wide Tensile	kN/m	20.5	25.3	19.3	30	17.8
Strength	Ratio	1	1.23	0.94	1.46	0.87
Wide Strip	%	70	7	6	11	5.4
Elongation	Ratio	1	0.10	0.09	0.16	0.08
Index	N	580	395	405	460	635
Puncture	Ratio	1	0.68	0.70	0.8	1.09
Permeability	10^{-3}m/s	3.75	0.015	0.7	0.135	2.6
	Ratio	1	0.004	0.187	0.036	0.693

Table 3: Comparative index properties of geosynthetics, geonatural and geocomposite

Properties	Unit/ Ratio	Geosyn-thetics	Geonatu-ral	Geocomposite
		GT*	Soil saver	GT-Soil saver
Unit weight	g/m^2	290	930	1220
	Ratio	1.00	3.21	4.21
Thickness	mm	2.35	3.95	6.3
	Ratio	1.00	1.68	2.68
EOS	mm	<0.075	1.18	<0.075
	Ratio	1.0	<15.7	1.0
Grab	N	1150	780	1740
Tensile Strength	Ratio	1.00	0.68	1.51
Grab Elongation	%	130	7	8
	Ratio	1.000	0.054	0.062
Wide Strip	kN/m	10.8	19.4	21.3
Tensile Strength	Ratio	1.00	1.80	1.97
Wide Strip	%	70	11	11
Elongation	Ratio	1.00	0.16	0.16
CBR Puncture	N	1900	1550	3160
Strength	Ratio	1.00	0.82	1.66
Permeability	10^{-3}m/s	2.67	25	7.25
	Ratio	1.00	9.36	2.72

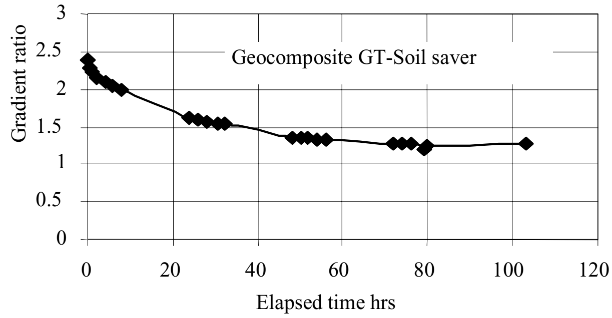

Figure 5 Gradient ratio test result for geocomposite

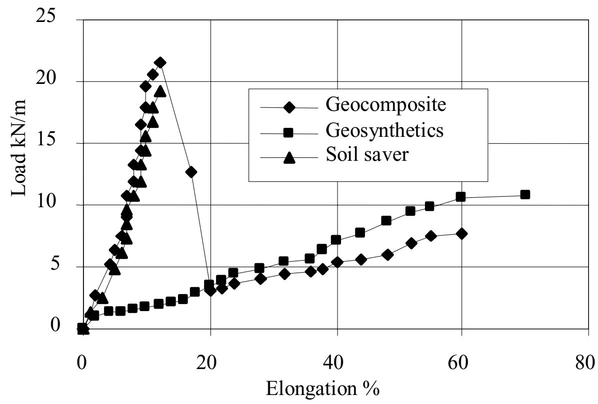

Figure 6 Load elongation behaviour of geocomposite

mainly, pore size and permeability. The strength related properties like tensile strength, puncture resistance and bursting resistance will show two phase material behaviour with two peaks at different elongation levels. This is due to the reason that, in most of the cases the elongations at failure of the components of the geocomposite will differ by a considerable degree. Test results showing wide width load elongation behaviour of the geocomposite GT-Soil saver are presented in Figure **6** along with those for the geosynthetics and the geonatural components.

These show the geocomposite to initially follow the stiffer geonatural curve and following its failure, falling to that of the weaker and more flexible geosynthetics. The geonatural in this case is more than ten times stiffer than the geosynthetics. Therefore, under this mode of loading, the geonatural will mobilise most of the resistance. Even if the geonatural is not very strong compared with the geosynthetics, it would mobilize most of the resistance due to its stiffness. Table 4 shows the summary of test results of the grades geocomposite relevant to filter application. Compared with the geosynthetics alone, the grades of geocomposite showed better grab tensile strength and puncture resistance. The grades GT-Twill showed marginal increase in these strengths. Burst test were conducted on GT-Felt and GT-coir only both showing increase over geosynthetics alone. Permeability of all of grades of geocomposite is greater than their geosynthetics counter part except grade GT-Canvas. The pore size results were found to be similar to those of permeability.

Table 4: Summary of test results

Geo composite	Unit wt	Grab strength	Puncture	Burst	Perme ability	Pore size
GT-Felt	5.8	1.5	0.4*	1.7	1.2	same
GT-Coir	7.3	1.5	0*	1.6	3.0	same
GT-Canvas	2.75	1.36	0.8+	-	0.036	same
GT-Twill	3.0	1.18	1.09+	-	0.693	same
GT-Soil saver	4.2	1.51	1.66+	-	2.72	same

- *indicates puncture hole test. + Puncture load test
- Figures in table are ratios wrt geosynthetics alone.

5 GEOCOMPOSITES AS FILTERS IN RIVER BANKS

Use of geocomposites as filter layers in river bank and bed protection is envisaged as one of the prime application areas. The geocomposite in this application should be able to withstand loading from three stages and function satisfactorily as filter layer in the short run as well as in the long run. The three stages are (a) during placing and sinking (b) during dumping of stones or concrete blocks and (c) under intended operational conditions.

A geocomposite, designated as GT-Sand-Soil saver, was constructed for this purpose. This is a modified form of GT-Soil saver (Table 3), which is of the type shown earlier in Figure 2. The geonatural Soil saver was chosen, as this fabric was heavy in weight and purpose constructed for geotechnical use. Moreover this was produced from waste jute making it cheaper than other grades of jute fabric. Longitudinal cells were sewn at 180 mm centers using polyester thread. These were filled with fine river sand to form filled longitudinal cells approximately 110 mm x 50 mm in cross-section. This type of geocomposite will be very suitable for this application providing, the required weight for easy sinking and placement, the right cushioning for dumping and placement of stones or blocks and finally, the intended primary function of filtration.

5.1 *Placement and sinking*

The loading of the geocomposite due to placement and sinking will depend on the method employed and such conditions as depth of placement, current velocity, wave height etc. The geocomposite GT-Sand-Soil saver, which will sink by its self weight, will allow continuous fabrication and placement on bank and from barge (Fig. 3). This is not possible in case of fascine mattresses which are fabricated, floated and sunk in finite pieces. The geocomposite will be filled with sand on the flat barge followed by sinking and placement in a continuous process. A 60m wide geocomposite having a weight of 76 kgsm was considered to be placed to a depth of 15 meters in a water current of 3 m/s. The geocomposite GT-Soil saver offered a factor of safety of more than 1.4, using calculation suggested by van Zanten 1986

5.2 *Damage due to dumping on geocomposite*

Dry and under water Dumping of stones or concrete blocks on geosynthetics filter is a very common construction stage activity. Various investigations reports about considerable damage of the geosynthetics filter due to this activity. Layers of reed, brushwood, sand or gravel are normally recommended to prevent damage due to dumping. In this study, the geocomposite GT-Sand-Soil saver has been designed to offer the required cushioning against puncturing and bursting due to dumping.

To simulate underwater dumping, drop tests in air, using concrete cubes was performed on the geocomposite. A 100 kg cubic concrete block was used to drop from a height of 0.4 m simulating its terminal velocity when dropped in water through 15 m (equation 1 van Zanten 1986).

$$x_m = \frac{c_2}{2gc_1}(e^{-2c_1x_p} - 1) \quad (1)$$

Where, C_1 = Calculation factor (1/m); C2 = Calculation factor (m/s); p and m = prototype and model subscripts; g = acceleration due to gravity (m/s^2); x = fall height in (m)

Twelve drop tests were conducted and no substantial damage was observed.

6 GEOCOMPOSITES AS GEOBAGS AND GEOTUBES

Geocomposite GT-Soil saver was used to construct geobags and geotubes in the laboratory. As described earlier the intended purpose of the heavy jute fabric was to endure stresses developing during construction and placement period. These stresses are developed due to filling by dredging, placement or dumping of the bags and tubes over and under water. Placement or dumping of stones/blocks and other bags on top of these bags and tubes will also impose considerable stress. The jute fabric is intended to endure the stresses during construction as well as service loads during the initial period of operation. On biodegradation of the geonatural, the geosynthetics partner of the geocomposite is intended to carry the stresses under operational condition.

Six geobags and four geotubes were constructed from the geocomposite GT-Soil saver described in Table 3. The geobags were 0.44m in diameter and 1.0m in length and filled with 0.11 m^3 of fine river sand. The geotubes were 0.8 m in diameter and 2.5 m in length and were filled with fine river sand. Drop test of bags were conducted from a height of 0.5 m to simulate fall in water through 15 m. Concrete block drop tests were conducted on bags and tubes using 100 kg cubic concrete blocks, falling in air, from a height of 0.4 m, simulating a 15 m fall through water. The bags and tubes endured the impact satisfactorily.

7 CONCLUDING REMARKS

Use of geocomposites made from combining geonaturals with geosynthetics show good promise in a number of applications. Well designed products coupled with the right production process may yield products for specific end uses. This will provide a cost effective solution to a number of problems at the same time open a good market for geonatural products. These, on their own, have very limited use in geotextile application.

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