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Technical Note

Stabilisation of soil using hybrid needlepunched nonwoven geotextiles

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ABSTRACT

In the past, natural and synthetic fibre based geotextiles have been used for short- and long-term applications of soil erosion. It is well known that these geotextiles complement each other in terms of various physical and mechanical properties. In this study, an attempt has been made to study various properties of hybrid geotextiles. These hybrid geotextiles have been produced from the blend of polypropylene/viscose and polyester/viscose fibres in defined weight proportions (0%, 20%, 40%, 60%, 80% and 100%). Subsequently, a comparison has been made between various physical and mechanical properties of needlepunched nonwoven geotextiles. In this research work, it was found that hybrid geotextiles made of viscose (up to 40 wt.%) can replace 100% polypropylene or polyester based geotextiles.

1. Introduction

Soil erosion due to rainfall or wind is highly detrimental to the environment and it can be reduced by growing and maintaining the dense cover of herbaceous vegetation (Gray, 1995; Mickovski et al., 2010). However, the growth of vegetation is slow and may not be uniformly spread in the desired region. Therefore, geotextiles are required to be used for uniform and rapid growth of vegetation in addition to fulfilment of reinforcement function. In general, geotextiles can be made from synthetic and natural fibres but the former fibre type has been widely used in civil engineering applications primarily due to their superior mechanical properties and long-term durability. Nevertheless, natural fibre based geotextiles are environment friendly, less costly, easily available, and ecologically compatible as they are degraded within the soil (Lekha, 2004; Sarsby, 2007). Several researchers have demonstrated the use of natural fibres including jute, flax, coir, wood and bamboo in various applications of geotextiles such as soil erosion control, vertical drains, road bases, bank protection and slope stabilisation (Ahn et al., 2002; Basu et al., 2009; Bera et al., 2009; Chauhan et al., 2008; Datye and Gore, 1994; Kaniraj and Rao, 1994; Lee et al., 1994; Lekha, 2004; Lekha & Kavitha, 2006; Park, 2009; Rao et al., 2000; Rawal and Anandjiwala, 2007; Sanyal and Chakraborty, 1994; Subaida et al., 2008, 2009; Slater, 2003; Tan et al., 1993). Particularly, jute and coir fibres have been successfully used for vegetal growth as they have high water absorption and moisture uptake which makes them ideal material for such applications (Lekha, 2004; Ranganathan, 1994). However, the coir geotextile was found to be degraded due to the microbial action in the soil in addition to the effect of rain and sun (Lekha, 2004). Furthermore, the coir net retained only 22% of its initial tensile strength at the end of seven months after it is deployed in the soil. Similar strength loss in coir netting was reported by Balan and Venkatappa Rao (1996). In addition, the natural fibres have inherent variation in properties that can result in loss of tensile strength (Rawal and Anandjiwala, 2007). Furthermore, in applications where natural fibres are exposed to microbiological agents and solar radiation, the effectiveness of these fibres is expected to reduce (Wall et al., 1971). The effect of solar radiation is not limited to natural fibres but synthetic fibres such as polypropylene also has a poor resistance to ultra-violet radiation (Zanten, 1986).

Cellulosic regenerated fibre such as viscose rayon is highly suitable for soil stabilisation applications as it is biodegradable, capable of holding water and has uniform inherent properties. However, it has low strength and stiffness in comparison to the synthetic fibres namely, polyester and polypropylene. Thus, the overall objective of the present work is to compare and analyse the properties of hybrid needlepunched nonwoven geotextiles produced from regenerated cellulosic and synthetic fibres (polyester and polypropylene) that can be potentially used for soil stabilisation applications. Furthermore, the changes in porosity of

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Table 1
Constituent fibre properties used in the production of nonwoven geotextiles.

Type of fibre	Linear density (dtex)	Length (mm)	Diameter (μm)	Modulus (GPa)
Polyester	5.3	50	22	2
Polypropylene	6.6	60	30	0.7
Viscose	4.2	60	18	0.2

geotextiles are computed by determining the reduction in thickness at a range of pressures.

2. Experimental

Viscose fibres were used in combination with synthetic fibres namely, polypropylene and polyester in defined weight proportions to produce needlepunched nonwoven structures. Subsequently, these structures were tested for various physical and mechanical properties as discussed below.

2.1. Sample preparation

Polypropylene/Viscose (PP/V) and Polyester/Viscose (PET/V) combinations were used in varying weight proportions (0%, 20%, 40%, 60%, 80% and 100%) to produce twenty-two sets of *hybrid* needlepunched nonwoven geotextiles. The constituent fibre properties are shown in Table 1. These structures were produced by initially opening and blending the staple fibres by means of carding and subsequently, orientated to cross-machine direction using a cross-lapper to form webs of required mass per unit area. These webs were then subjected to the needlepunching process to produce the nonwoven geotextiles. It must be noted that the process parameters were kept constant except the feeding rate to the card, which was varied to obtain desired geotextiles of mass per unit area of 200 and 400 g/m^2.

2.2. Testing of needlepunched nonwoven geotextiles

Twenty-two sets of needlepunched nonwoven geotextiles were tested for various physical and mechanical properties. Geotextile thickness was measured at pressures of 2, 20 and 200 kPa for

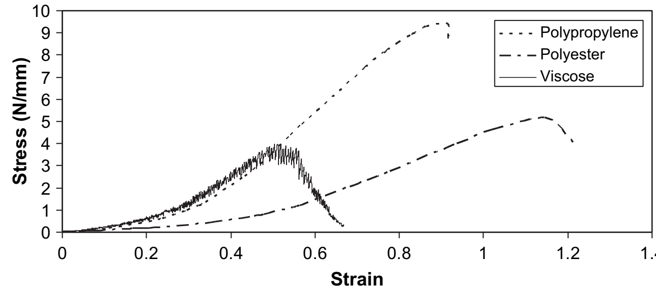

Fig. 1. Typical stress–strain curves of 100% polyester, 100% polypropylene and 100% viscose based geotextiles of mass per unit area of 200 g/m^2 in the machine direction.

determining the changes in porosity. The porosity of geotextile was calculated under defined normal pressures using Eqs. (1) and (2).

$$\eta = 1 - \frac{G}{T\rho} \tag{1}$$

and

$$\rho = \frac{\rho_1 \rho_2}{x\rho_2 + (1-x)\rho_1} \tag{2}$$

where x is the weight proportion of fibres in hybrid nonwoven geotextile, ρ is the *equivalent* density of fibres (subscript 1 or 2 refers to fibre types), η, G and T are porosity, mass per unit area and thickness of geotextile under defined loading condition, respectively.

Furthermore, the mechanical properties including tensile and puncture resistance were determined according to the standard test methods, ISO 9073-3 (1989) and ASTM D4833 (2001), respectively. In general, nine specimens were replicated for each test.

3. Results and discussion

3.1. Physical properties of hybrid needlepunched nonwoven geotextiles

Nonwoven geotextiles used for vegetation purposes need to have maximum porosity for keeping the seeds and fertilizers specifically under defined loading conditions. Table 2 shows

Table 2
Physical properties of nonwoven geotextiles.

Fibre type (s) and percentage content in geotextiles			Fabric mass per unit area (g/m^2)	Thickness (mm)			Porosity			Percentage change in porosity	
Polyester %	Polypropylene %	Viscose %		2 kPa	20 kPa	200 kPa	2 kPa	20 kPa	200 kPa	2–20 kPa	2–200 kPa
100	–	0	200	2.61	2.17	0.77	0.94	0.93	0.81	1.19	14.05
80	–	20	200	2.17	1.68	0.60	0.93	0.92	0.76	2.04	18.30
60	–	40	200	1.81	1.48	0.47	0.92	0.91	0.70	1.86	23.84
40	–	60	200	2.10	1.48	0.82	0.93	0.91	0.83	2.92	10.89
20	–	80	200	2.16	1.93	0.90	0.94	0.93	0.85	0.79	9.28
0	–	100	200	1.81	1.46	0.67	0.93	0.91	0.80	1.88	13.34
–	100	0	200	2.61	2.22	1.02	0.92	0.90	0.78	1.62	14.33
–	80	20	200	2.08	1.78	0.73	0.90	0.89	0.72	1.82	19.92
–	60	40	200	2.21	1.95	0.81	0.92	0.91	0.77	1.21	15.74
–	40	60	200	1.81	1.63	0.63	0.91	0.90	0.74	1.12	19.03
–	20	80	200	2.01	1.77	0.83	0.93	0.92	0.82	1.09	11.40
100	–	0	400	2.76	2.45	0.98	0.89	0.88	0.70	1.48	21.31
80	–	20	400	2.75	2.22	0.83	0.90	0.87	0.66	2.75	26.61
60	–	40	400	2.97	2.65	1.56	0.91	0.89	0.82	1.25	9.38
40	–	60	400	2.89	2.54	1.18	0.91	0.89	0.77	1.44	15.18
20	–	80	400	3.31	2.88	1.48	0.92	0.91	0.82	1.32	10.92
0	–	100	400	2.97	2.75	1.40	0.91	0.90	0.81	0.78	10.90
–	100	0	400	3.07	2.39	1.75	0.86	0.82	0.75	4.75	12.60
–	80	20	400	3.17	2.68	1.48	0.87	0.85	0.73	2.67	16.70
–	60	40	400	3.56	3.19	1.88	0.90	0.88	0.80	1.34	10.33
–	40	60	400	2.97	2.49	1.37	0.89	0.87	0.76	2.44	14.79
–	20	80	400	2.99	2.67	1.78	0.90	0.89	0.83	1.33	7.54