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GEOTEXTILES IN FILTRATION AND DRAINAGE

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ABSTRACT

Geotextiles have been used successfully as filters [for cross plane flow], drains [for plane flow], or both. Geotextile drainage occurs either cross plane or in-plane. In regard to drainage, the cross-plane permeabilities of all the geotextiles currently in use are sufficient for most situations. But it is not meaningful if geotextiles are subjected to dynamic load. The selection of geotextile criteria give empirical limiting values to the ratios of geotextile pore size to the soil particle size. Under dynamic loading condition, they do not give a quantitative measure of the amount of contamination likely to occur in railway ballast materials due to mud pumping. In this investigation in-plane permeability at various stress levels and cross plane permeability tests on geotextiles were conducted. In addition a series of simulated mudpumping tests in soil dynamic tester were conducted using various combination of soil and geotextiles. The effect of stress level on in-plane permeability and the effect of type of soil and geotextile and frequency of load application on SCV and deformation was studied. Various criteria used for geotextiles for reversible flow conditions were used to check whether the geotextiles satisfy the criteria. The SCV were considered in each case. An attempt is made to correlate SCV to the criteria based on the pore size of the geotextile and particle size of the soil.

INTRODUCTION

Geotextiles can be used in filtration and drainage systems in much the same way as soil filters and drains; their advantages over soils, however, are numerous. Depending upon the situation, those advantages can include:

* Less excavation
* Faster installation
* Tensile strength of the geotextile added to the system
* Less soil to dispose of
* Greater system stability
* Less technical details in planning and construction.

Mud pumping is a major problem in railways and requires regular maintenance. The dynamic load imposed by a moving train can induce a problem known as erosion pumping failure. When the ballast rests on subgrade, water reaching the subgrade from either a high water table or rainfall can turn the cohesive soil into a slurry which is pumped upwards through the ballast by alternating contraction and expansion of voids under dynamic loads. This contamination of track ballast will reduce its load supporting properties, eventually leading to unacceptable movement of the rails.

GEOTEXTILE FILTERS

The two main criteria for selecting an appropriate geotextile to form a filter are soil-tightness and permeability. The soil tightness criteria places a upper limit on the geotextile pore size. Whereas the permeability criteria place a lower limit on the geotextile pore size. For reversing flow conditions geotextile openings have to be smaller to restrain soil particles than for unidirectional flow. The environments in which geotextile filters have to perform can be subdivided into three categories, based upon the flow conditions. These are

(i) Fairly steady unidirectional flow
(ii) Reversing flow with a moderate cycle time
(iii) Reversing flow with a very short cycle time.

Examples of applications corresponding to these conditions are respectively .

(i) Land drainage
(ii) River and coastal defencefilters
(iii) Anti-pumping filters beneath railway ballast

The following are some of the uses of geotextiles conducting or transmitting water through its body in the direction parallel to the plane of geotextile.

* Geotextile under railway track
* Geotextile used as horizontal filters in earth dams.
* As interceptors for load drains.
* As drainage layers to improve consolidation properties of subsoil
* As dissipator of excess hydrostatic pressure behind retaining walls, etc.,

The various criteria used in different countries for selecting the non-woven geotextiles in reversing flow conditions are given in Tables 1 to 4 (John, 1987).

Permeability criteria for reversing flow conditions are

$k_g \geq 10\ k_s$ for sand ... (1)

$k_g \geq 100\ k_s$ for clay ... (2)

TABLE - 1 GERMAN CRITERIA

Soil Description	Geotextile Criteria
$d_{40} > 0.06$ mm	$D_W < d_{90}$
$d_{40} \leq 0.06$ mm	$D_W < 1.5\ d_{10} \sqrt{U}$ and $D_W < d_{50}$ and $D_W < 0.5$ mm

D_w - Significient Pore size

TABLE -2 DUTCH CRITERIA

Soil Conditions	Geotextile Criteria
With granular filter layer	$O_{98} \leq 2\ d_{85}$
Without a granular filter layer	
a) Non - criticial applications	$O_{98} \leq 1.5\ d_{15}$
b) Critical applications	$O_{98} \leq 1.0\ d_{15}$

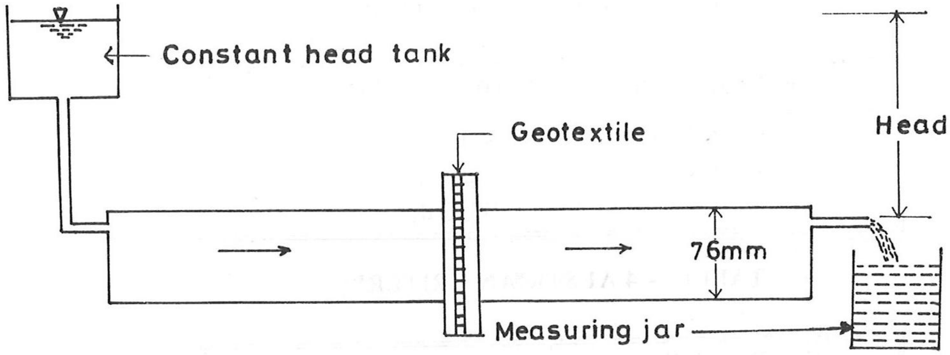

FIG.1. CROSS PLANE PERMEABILITY SET UP

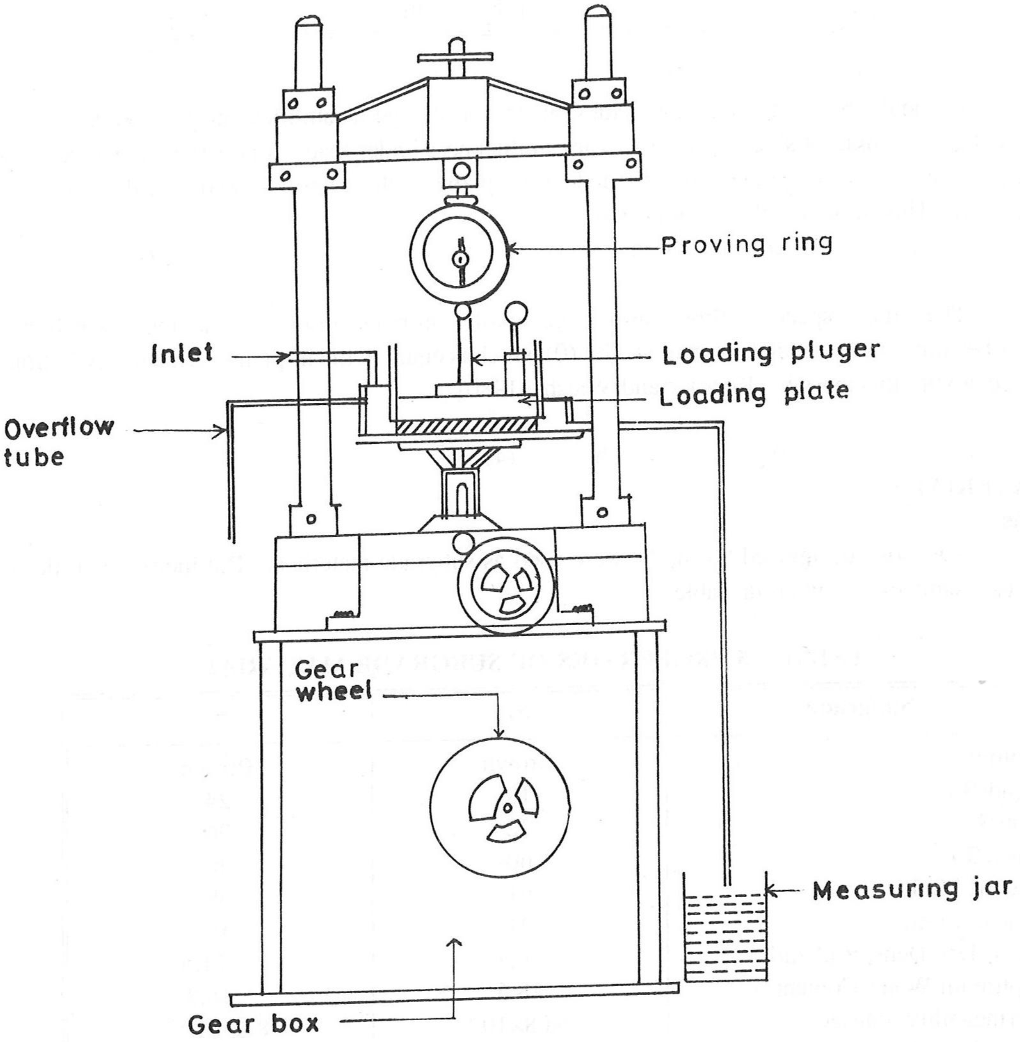

FIG.2. IN. PLANE PERMEABILITY SET UP

TABLE - 3 AMERICAN CRITERIA

Soil Description	Geotextile Criteria
$d_{50} > 0.074$mm	$0_{50} \leq d_{85}$
$d_{50} \leq 0.074$mm	$0_{95} \leq d_{15}$ or $0_{50} \leq 0.5\ d_{85}$

TABLE - 4 AUSTRIAN CRITERIA

Soil Description	Geotextile Criteria
$U > 5$ and $d_{80} < 0.06$mm	$D_w < d_{80}$ $D_w \leq 0.1$mm and $T_g \geq 2$ mm

It should be noted that the values given for the permeabilities of geotextiles are not particularly meaningful since geotextiles vary in thickness under load. It is better to use the value of k_n/h where k_n is the permeability normal to the plane of the geotextile and h is the geotextile thickness. This term is called permittivity (ψ)

$$\psi = k_n/h \qquad \text{... (3)}$$

The other aspect of flow through geotextiles in-plane drainage, the term which best describes this characteristic is transmissivity (θ) which is equal to the in-plane permeability k_p times the geotextile thickness h. [Koerner and Walsh , 1980)

$$\theta = k_p * h \qquad \text{- (4)}$$

MATERIALS

Soils

Two soils designated S_1 and S_2 were used as subgrade materials. The index properties of the two samples are given in Table -5

TABLE - 5 PROPERTIES OF SUBGRADE MATERIALS

Subgrade	S_1	S_2
Colour	Brown	Brown
Sand(%)	18	24
Silt(%)	22	36
Clay(%)	60	40
Liquid Limit	61	39
Plastic Limit	21	16
Max. Dry Density kN/m^3	16.7	21.6
Optimum Water Content %	18.5	16.8
Permeability, cm/sec	6.08×10^{-8}	8.63×10^{-6}
Soil Classification	CH	CI

Aggregate: A 20mm aggregate was used as a ballast material.

Geotextiles

Three non-woven needle punched geotextiles manufactured from polypropylene were used as filters. The Effective Opening Size (EOS) of the geotextiles are found out by sieving various size of clean dry sand through the geotextile. [Indian Railways, 1990] Table-6 gives the properties of geotextiles.

TABLE - 6. PROPERTIES OF NONWOVEN GEOTEXTILES

Geotextile	G_1	G_2	G_3
Specification	CNPP-1(8)	HG-22	CNPP-5
Manufacture	Charms Pvt.Ltd	Hitkari Fibres Ltd.	Charms
Wt/sq.mt-gm	180 ± 10	225 ± 10	500 ± 10
Thickness(mm)	1.8	2.27	3.8
EOS (0_{95}) (Microns)	95	125	145
Coefficient of permeability (100mm head), cm/sec	7.4×10^{-3}	6.0×10^{-3}	5.3×10^{-3}

The cross plane permeability of geotextile was determined by allowing the water to flow through a geotextile samples clamped between the circular flages of pipes of 76 mm diameter (Figure - 1) at a constant head of 100 cm.

The experimental set up for determining the transmissivity is shown in Fig - 2. Geotextile sample of size 20 cm x 20 cm was cut and soaked in water for 24 hours. The geotextiles was placed in the permeability cell and the load was applied. Normal stress was increased from 20 kN/m^2 to 200 kN/m^2 in increment of 20 kN/m^2 and then increased to 400 kN/m2 in increments of 50 kN/m^2. Table 8 gives the thickness, In-plane permeability and Transmissivity values of different non-wover geotextiles. Fig 3 and 4 shows the variation of Inplane permeability and Transmissivity with applied normal stress. It is observed that the in-plane permeability coefficient and transmissivity values decreases markedly by in the initial stress ranges of 20 kN/m^2 to 80 kN/m^2 and marginally in the latter stress ranges.

DYNAMIC TEST

The SDT-1000 soil dynamic tester used in the investigation is primarily designed for repetitive loading application of soils and other low strength materials. The maximum frequency that can be applied is 40 cycles per minute and minimum frequency 2 cycles per minute. The arrangement for repetitive load test is shown in Figure - 5. The compaction energy applied for subgrade is equivalent to proctor energy. The geotextile filter was positioned on top of the subgrade by forming a circular disc approximately 200 mm diameter. After weighing, the geotextile was place on the subgrade with extra material turned up the sizes of the mould, clean dry aggregate of 20mm size weighing 1.25 kg was placed over the geotextile filter. The ponded water was simulated by pouring 500 cc of water into the mould gently. The sample was then left to stand for 48 hours to ensure diffusion of water into the soil. After 48 hours the sample was placed on the loading platform of SDT and the repetitive loads were applied.

The modern broad gauge electrical and diesel locomotives weighing about 113 tonnes are expected to transmit a load of 225 kN / m^2 when moving at a speed of 100 - 120 km per hour. In this present investigation the load intensity applied as 0.6 times the above intensity (i-e) 140 kN / m2 and it was maintained for 5000 repetitions. After the test, the contaminated fabric was dried and weighed. The soil contamination value was taken as the weight of subgrade soil passing the filter per unit area of the filter. The deformation under repetitive loading was measured by LVDT. The

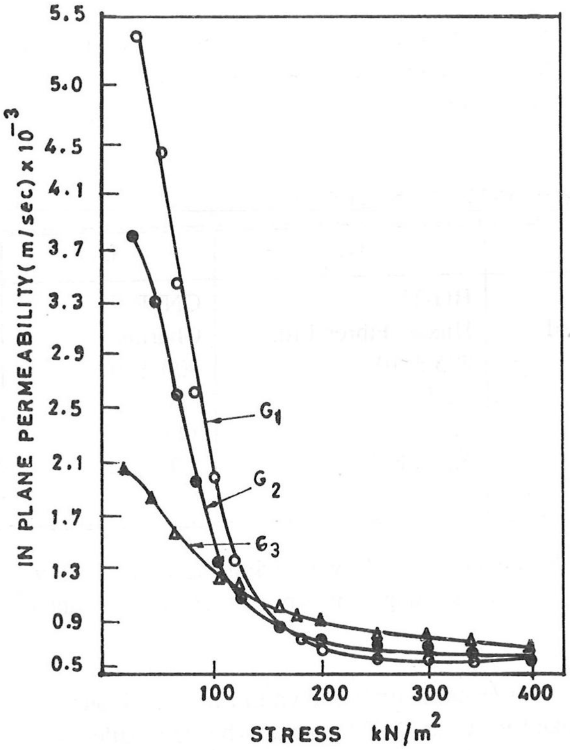

FIG. 3. VARIATION OF IN-PLANE PERMEABILITY WITH STRESS

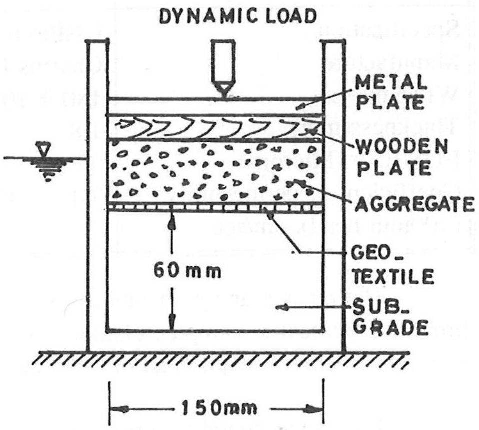

FIG. 5. DYNAMIC LOAD TEST

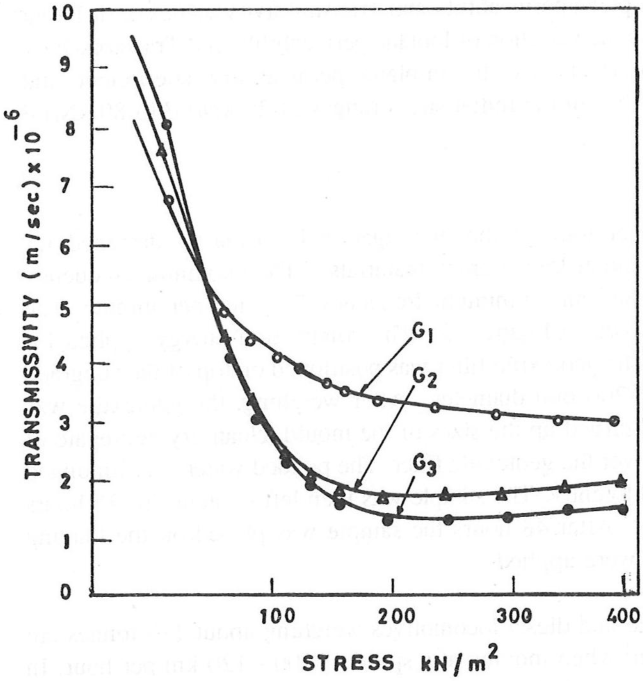

FIG. 4. VARIATION OF TRANSMISSIVITY WITH STRESS

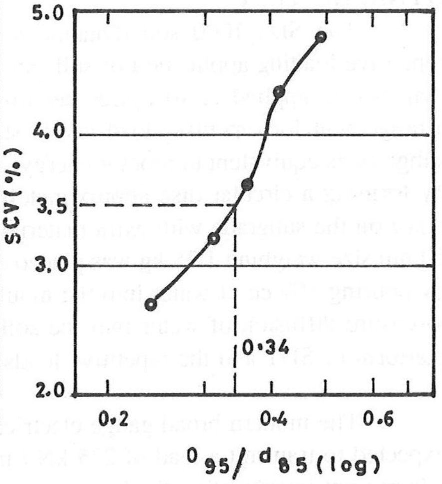

FIG. 6. RELATION BETWEEN SCV AND O_{95} / d_{85}

relative influence of the type of subgrade and the type of geotextile filter used on SCV and deformation is shown in Table - 8.

TABLE- 7 INFLUENCE OF STRESS ON GEOTEXTILE PERMEABILITY CHARACTERISTICS

Type of Geotextile	Thickness(mm) Under		Inplane permeability m/sec under		Transmissivity m / sec under	
	$140\ kN/m^2$	$400\ kN/m^2$	$140\ kN/m^2$	$400\ kN/m^2$	$140\ kN/m^2$	$400\ kN/m^2$
G_1	1.46	1.33	1.10×10^{-3}	0.65×10^{-3}	1.61×10^{-6}	0.86×10^{-6}
G_2	1.92	1.78	0.94×10^{-3}	0.71×10^{-3}	1.8×10^{-6}	1.26×10^{-6}
G_3	3.32	3.17	1.1×10^{-3}	0.76×10^{-3}	3.75×10^{-6}	2.41×10^{-6}

For both the soils the SCV and deformation increased with increasing EOS, SCV was more for the soil having a greater clay content (S_I). It is observed that the SCV can be reduced by having a geotextile of smaller pore size in soils having a large amount of clay. It was also evident that the deformation was larger when geotextiles were not used.There was a small reduction in SCV and deformation with increase in frequency.

TABLE - 8 INFLUENCE OF TYPE OF SUBGRADE AND GEOTEXTILE

Frequency: 40cpm Stress Level : 140 kN / m^2 No.of Repetitions: 5000

Sub-grade Type	Geotextile Type	O_{95} / d_{85}	SCV%	Deformation mm
S_1	No filter	-	-	19.2
	G_1	0.32	3.39	11.7
	G_2	0.42	4.24	12.8
	G_3	0.48	4.70	13.6
S_2	No filter	-	-	18.0
	G_1	0.24	2.63	11.1
	G_2	0.31	3.13	12.0
	G_3	0.36	3.55	13.2

FILTER CRITERIA

The criteria shown in Table 1 to 4 are applied to the various combinations of subgrade and geotextiles to check the suitability of geotextiles. Table 9 shows the results. American criteria was found to be least restrictive as all the combinations satisfied the criteria. Dutch and German criteria were most restrictive as none of the combinations satisfied them.

TABLE - 9 SUITABILITY OF GEOTEXTILES

Sub grade	Geotextile Suitable Under			
	American Criteria	German Criteria	Austrian Criteria	Dutch Criteria
S_1	G_1, G_2, G_3	---	G_1, G_2, G_3	---
S_2	G_1, G_2, G_3	---	---	---

The acceptable SCV value for the American Criteria is 4.7% for the combination of S_1 and G_3. For Austrian criteria the acceptable value is 3.13 for the combination of S_2 and G_2.All the combination of soils and geotextiles satisfy the permeability criteria.

CRITERIA BASED ON o_{95} / d_{85} RATIO

The soil contamination values and the corresponding o_{95} / d_{85} ratios are plotted on a semilogarithmic plot (Table - 8 and Figure - 6). For a contamination value of 3.5% the correpsonding o_{95} / d_{85} ratio was found to be 0.34. Hence it is suggested that the following criteria may be used so that the contamination value is within 3.5%.

$$o_{95} \leq 0.34\ d_{85} \qquad \ldots \qquad (7)$$

CONCLUSION

1. The in-plane premeability coefficient and transmissivity decreases with increase in applied normal stress on the geotextgile.

2. Decrease in in-plane permeability coefficient is more pronounced in the intial stages of stress increase than in the later stages.

3. When applied normal stresses are removed gradually, it is dobserved that the orignal permeability value of the geotextile are not regained, indicating that some permanent structural changes taking places in the geotextile itself.

4. All the geotextiles satisfied the permeability criteria.

5. The results of dynamic load tests indicated that SCV and deformation increased with increasing percentage of clay in the soil, increasing EOS of the geotextile; but increase in frequency caused a reduction in SCV value and deformation.

6. For an allowable SCV of 3.5% of ratio of 0_{95} / d_{85} can be taken as 0.34.

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