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Comparative Study of Various Soils Upon Addition of Different Materials on the Basis of Hydraulic Conductivity Parameter

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***Abstract*: While selecting various additives for different soils in the process of stabilisation or reinforcement, one must also think upon the variations occurring in the permeability parameter because of the after-effect of addition of additives so as to ensure that well drainage function is being maintained within the soil mass. If not, the clogging of pores following the condition of water logging may result as the adverse effect of adding additives. In the present article, the change in hydraulic conductivity has been studied upon different type of soils with different additives.**

Keywords: Hydraulic conductivity (HC), Permeability, Clayey Soil, Sandy Soil, Powdered Additives, Fibre Additives, Rice Husk Ash (RHA), Fly Ash (FA), Stone Dust, HDPE, PP.

I. INTRODUCTION

Hydraulic conductivity is a decisive as well as crucial characteristic of soil when the talk is about the drainage function (fluid transmission) and change occurring within the soils. The other name commonly used to refer hydraulic conductivity is coefficient of permeability (K). Hydraulic conductivity is mainly dependent upon several factors such as the type of soil, its particle size distribution, chemical composition, and degree of saturation and the account of entire data of stress distribution within soil. Darcy (1856) first stated and derived the empirical formula to determine the hydraulic conductivity of soil which is referred commonly as Darcy's law. Darcy's law can be stated as under:

$$Q = K\, i\, A$$

Where, Q = flow rate (volume/time); K = hydraulic gradient or coefficient of permeability (length/time); i = hydraulic gradient (unit less); A = unit cross-sectional area (area) respectively. From past references, value for hydraulic conductivity of various soil can be shown in the tabular form as below:

Table 1: Typical values of hydraulic conductivity for various soils based on past literatures

Type of Soil	Hydraulic conductivity K (cm/sec)	Remarks
Gravel	1.00E-01	Very High
Coarse Sand, Fine Sand	1.00E-03 < K < 1.00E-01	High to Medium
Silty Sand	1.00E-05 < K < 1.00E-03	Low
Silt, Silty Clay	1.00E-07 < K < 1.00E-05	Very Low
Clay	< 1.00E-07	Tends to Impermeable

Various practices are performed to determine the hydraulic conductivity. Of which the most commonly adopted methods to determine the HC are Laboratory methods (Constant head and falling head method respectively). Various other methods to determine hydraulic conductivity can be tabulated in brief as below:

Table-2 Hydraulic conductivity methods in various fields

<table>
<tr><td rowspan="15">Hydraulic Conductivity Determination Methods</td><td rowspan="11">Hydraulic methods based on Darcy's law (Experimental approach)</td><td rowspan="9">In-situ field methods</td><td rowspan="2">Large scale methods</td><td colspan="2">At existing drains</td></tr>
<tr><td colspan="2">At tube-wells (Pumping tests)</td></tr>
<tr><td rowspan="7">Small scale methods</td><td rowspan="5">Below water table</td><td>Augerhole</td></tr>
<tr><td>Piezometer</td></tr>
<tr><td>Guelph</td></tr>
<tr><td>Double tube</td></tr>
<tr><td>Pumped borehole</td></tr>
<tr><td rowspan="2">Above water table</td><td>Infiltrometer</td></tr>
<tr><td>Inversed augerhole</td></tr>
<tr><td rowspan="2">Laboratory methods</td><td colspan="3">Constant head</td></tr>
<tr><td colspan="3">Falling head</td></tr>
<tr><td rowspan="4">Correlation methods (Empirical approach)</td><td colspan="4">Pore size distribution</td></tr>
<tr><td colspan="4">Grain size distribution</td></tr>
<tr><td colspan="4">Soil texture</td></tr>
<tr><td colspan="4">Soil mapping unit</td></tr>
</table>

II. MATERIALS

11 different types of soil were used for the study on the basis of grain size distribution. Based on the GSD, from coarser to finer, they are stated as below with different intrinsic properties:

Table-3 Coarse grain Soil

Soil	Type	G	LL	PL	Gravel	Sand	Silt-Clay	K(cm/s)
Soil-1	SM-SC	-	17.00	10.90	27.46	49.42	23.11	1.54E-04
Soil-0	SM-SC	-	36.42	20.70	24.77	35.61	39.62	9.80E-05
Soil-4	Clayey-Sand	-	49.00	23.00	00.00	80.00	20.00	8.00E-05
Soil-10	SW-ML	2.68	23.00	17.80	00.00	83.00	17.00	4.20E-06
Soil-7	Sand	2.50	-	-	00.00	100.00	00.00	6.13E-07
Soil-9	SM-SC	1.99	46.00	21.00	00.00	71.00	29.00	8.61E-10

Table-4 Fine Grain Soil

Soil	Type	G	LL	PL	Gravel	Sand	Silt-Clay	K(cm/s)
Soil-2	CL	-	44.45	25.97	14.13	25.20	60.67	6.90E-05
Soil-3	MH	-	53.59	32.13	03.20	20.42	78.38	5.60E-05
Soil-5	A-7-6 (OH)	2.66	45.51	25.35	02.53	44.93	52.54	1.03E-05
Soil-6	BCS	-	55.00	32.00	00.00	19.16	80.84	3.40E-07
Soil-8	CH	2.61	60.00	32.00	00.00	20.45	79.55	5.13E-07

These are the following wastes that are being used in the study which is divided into two tables as (table-5) for fine (powdered form) waste and (table-6) for fibre waste:

Table-5 Properties and components of Fine Waste

Sr.	Type	Materials	Components with specifications						
			SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O
Soil-0	SM-SC	RHA							
Soil-1	SM-SC		79.66	2.21	0.52	0.65	0.87	0.019	1.98
Soil-2	CL		specific gravity -1.63, bulk density- 588.53						
Soil-3	MH								
Soil-5	A-7-6	RHA	Local rice millers by Oyetola and Abdullahi (2006).						
Soil-9	CL	RHA	72.24	4.2	3	4.12	1.7	S G-1.87, Lime R-34	
Soil-6	BCS	stone dust	70.74	20.67	2.28	-	1.57	-	-
Soil-6	BCS	Lime	1.0-12	0.5-40	-	3.5-40	2.5-25	S03(0.2-3), Alkali (0-4)	
Soil-9	CL	Fly Ash	61	16.9	7.24	3.74	2.4	2.7	1.07
Soil-10	SW-ML	Fly Ash	-	-	-	-	-	-	-

Table-6 Properties of Plastic waste

Sr.	Type	Materials	Components with specifications
Soil-4	Clay	Fibre	10 mm to 25 mm
Soil-6	BCS	Fibre	T S-(553-759 mpa), Y's M-3450 mpa, S G-0.9, M P-(0160-170 0C)
Soil-7	Sand	PET	L (mm)-6, W(mm)-0.2, S G-1.33, T L(N)-350
Soil-8	CH	PP	12 mm length, aspect ratio 300, S G was 0.91, M P was 1600 C

III. TEST METHODOLOGY AND PROCEDURE

This study methodology is totally based on hydraulic conductivity which is a very vital part in many engineering areas. Generally, laboratory methods are used for the determination of hydraulic conductivity viz. constant head test and falling head test respectively. IS 2720: Part 17 is referred to perform the constant head and falling head test as per Indian Standards. Other international codes referred to perform these experiments are ASTM D5856 [9] and ASTM D2434 [10]. Hydraulic conductivity depends upon these factors.

i. Grain size distribution
ii. Pore size distribution
iii. Fluid viscosity
iv. Void ratio
v. Degree of saturation

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The two methods used for the determination are explained as below:

a. Constant Head Test

This test is usually performed on coarser grain soil because of the rate of water flowing through permeameter is greater than 10^{-4} cm/sec i.e. we get the constant flow of water as the assumption said in case of laminar flow. The value of k is independent of hydraulic gradient i. Referring code of this test method is ASTM D2434 as well as IS 2720: Part-17

b. Falling Head Test

Falling head test is used for both the types of soil namely coarse grain and fine grain soil. Functioning in this test is similar but the setup is different as soil do not give a constant flowing rate of water likewise the procedure is also varying from the constant head test. The methodology and procedures are well stated in IS 2720: Part-17.

IV. RESULTS AND DISCUSSIONS

After the admixtures/additives were added into the coarse grained soils, following results were obtained and the change in permeability is shown as below with a result table and comparison graph:

Table-7 Permeability effect on the coarse grain soils

Sr.	Soil	Materials	Percentage used	Reference	Effect on Permeability
Soil-1	SM-SC	RHA	(3%, 5%, 7%,	[1]	Permeability decrease with increase of RHA
Soil-0			10%, 15%)		
Soil-4	Clayey Sand	natural fibre	(0.1%, 0.2%, 0.3%)	[2]	Permeability increase with fibre content and length increase
			10 mm to 25 mm		
Soil-10	SW-ML	Fly Ash	20%,30%	[8]	permeability decreases with increase of fly ash in soil
Soil-7	Sand	Plastic waste	(0.5%, 0.75%, 1%)	[6]	Permeability of sand decreases with an increase in 1% plastic
Soil-9	CH	Fly Ash	(5%,10%,15%,20%,	[7]	Permeability of soil increased on admixing FA and RHA
		RHA	25%, 30%, 35%)		

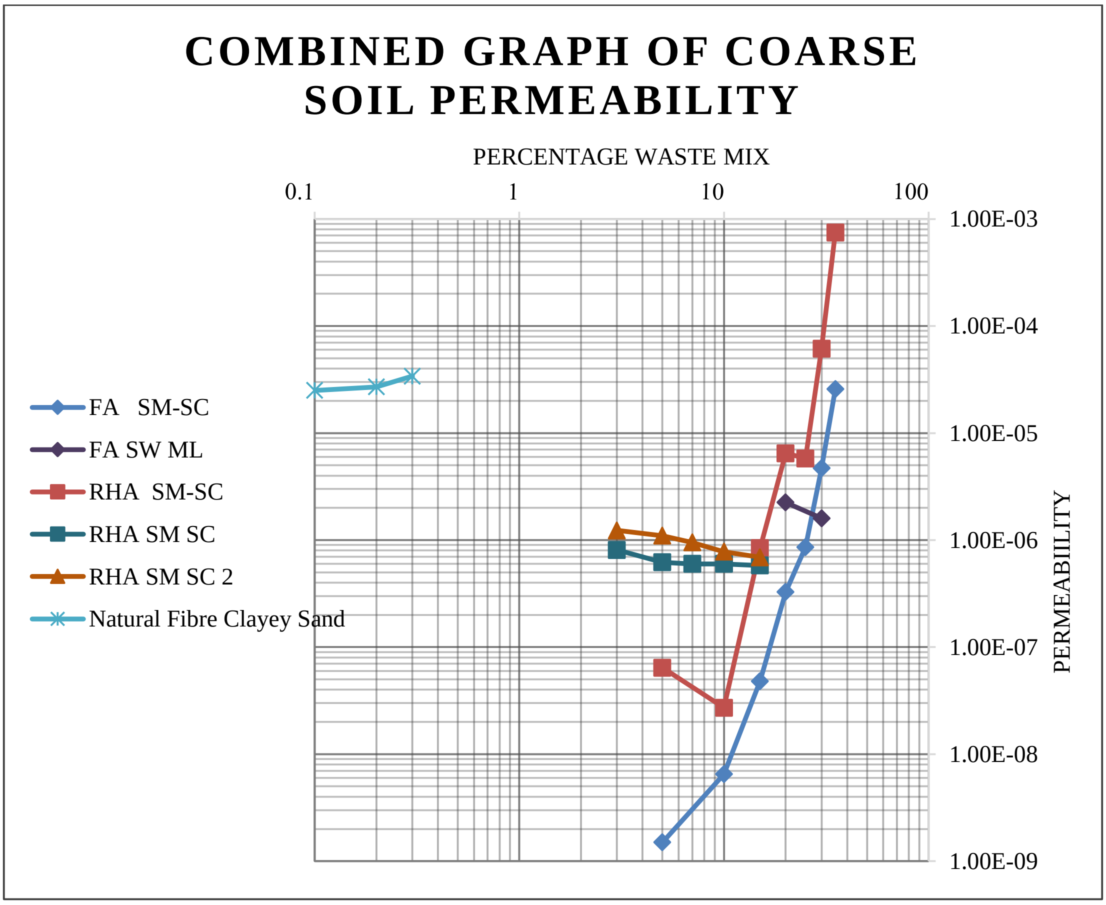

Fig-2 Coarse Grain Soils v/s permeability

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After the admixtures/additives were added into the fine grained soils, following results were obtained and the change in permeability is shown as below with a result table and comparison graph:

Table-8 Permeability effect on fine grain soils

Sr.	Soil	Material	Percentage	Reference	Permeability effect
Soil-2	CL	RHA	(3%, 5%, 7%, 10%, 15%)	[1]	Permeability decrease with increase of RHA
Soil-3	MH	RHA			
Soil-5	CH	RHA& Lime	(2%, 4%, 6%, 8%)	[3]	Permeability decrease with increase of 4 to 6% RHA
Soil-6	BCS	HDPE waste fibres, Stone dust & LIME	(0.5, 1.0, 1.5)	[4]	Permeability decrease with increase of %stone dust & Lime
			(5,10,15),		
			(3,6,9)		
Soil-8	CH	Polypropylene	0.5%,1.0%,1.5%,2.0%	[5]	hydraulic conductivity goes on increasing with increase in % of PP fibre

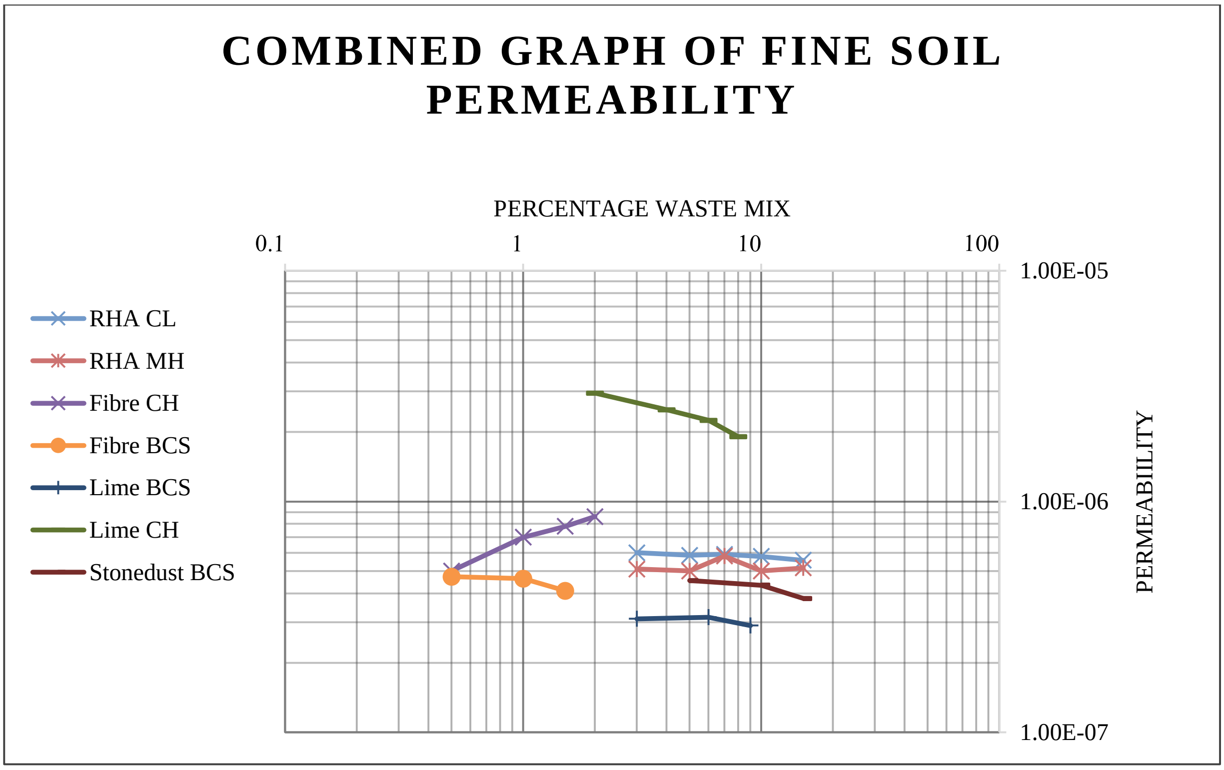

Fig-3 Fine Grain Soils v/s permeability

V. CONCLUSIONS

Through this paper, we can easily figure out that behaviour of the soil HC (permeability) is different with materials with respect to percentage and proportions of mixing. The after-effects of additives on various soils is briefed as below:

a) As in fig-1 and table-7 we have clearly seen that coarser soil with gradual increase in addition of ash content decreases the permeability of soil.
b) As in fig-1 and table-7 we observed that CH soil when mixed with lime results in decrease of hydraulic conductivity.
c) Whereas in fig-2, we can see that when fibre or plastic waste is mixed with various soil, hydraulic conductivity gets increased in the soil.
d) But addition of fibre in pure sand gives result otherwise. The hydraulic conductivity is significantly decreased.
e) For soil like BCS in fig-2 and table-8, we find that permeability decreases with lime at 4% and 8% and similar results were obtained for stone dust.
f) In fig-2 and table-8 we observed that with the use of RHA in soil CL, permeability got reduced to a considerable extent.

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