Investigation and Characterization of Soil for River Bank Filtration System

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Abstract. Soil study has been done to check soil suitability for River Bank Filtration (RBF). A Somlapura village on the bank of Tungabhadra River is selected as study site. In study site 3 different soil samples were collected from 3 different locations to understand the characteristics of soils at a river bank (i.e. Soil texture and permeability). The report of grain size analysis of these 3 samples showed that the soil consists of gravel and sand, which are porous in nature. The permeability test results of soil samples 1, 2, and 3are 1.16×10^{-3}cm/sec, 7.67×10^{-3}cm/sec, and 3.87×10^{-3}cm/sec respectively. The maximum permeability of soil sample 2 at site 1 is 7.67×10^{-3} cm/sec. The soil which has the maximum permeability is more likely to be suitable for the River Bank Filtration application.

Keywords: River Bank Filtration, Soil texture, Porosity, Permeability

1   Introduction

The texture and permeability of soil plays vital role in defining fitness of a location for implementation of RBF technique. Soil investigations may be performed into two methods: the first is known as reconnaissance (surface investigation) and the second is known as sub surface investigation. The second method is adopted to check soil suitability for implementation River Bank Filtration System. River Bank Filtration is type of water purification method by allowing water to pass through the bank of river or lake; it is then drawn off by extraction wells drilled on the bank of river or lake. In this system bank material acts as a porous medium through which water seeps. Therefore, it is necessary to understand the properties of this porous medium. A study was conducted by Adlan et al., in 1757[1] to find the characteristics of the soil on a Sungai Perak riverbank for unlike strata of a well and 3 nearby observation wells - OW_2, 3, and 5. Size distributions of soil particles and permeability values were found from sieve analysis &Permeameter respectively. Similar study related to soil analysis of borehole near Kerian River, Malaysia [2] featured clay, sandy clay loam and sandy loam. A study on an aquifer with multi-layers, characteristic of sedimentary deposit of riverbank at Korea [3,4], to find the hydrologic characteristics. Many studies were

conducted on river bank projects and they proved that, river bank sand material used as filter material [5]. From available research works, it is found that soil texture and its permeability will play important role in deciding the water quality and a yield from a RBF well. The present study is to assess the grain size and permeability of the selected soil samples to check its suitability for RBF system on the bank of Tungabhadra River, Karnataka, India.

2   Study Area

A Somlapura village on the bank of Tungabhadra River is selected as a study site. Somlapura is a small village of Ranebennur (tq.), Haveri(dist.), Karnataka state, India. It is situated 48 km towards an East of district headquarters, 20 km from Ranebennur and 319 km from capital of state i.e., Bangalore. According to 2011 census the population of the village is 1484. The Figure1 displays the geographical position of study area.

Fig.1. Location of the Study Area

3   Methodology

Soil samples were obtained from the study site during the construction and development of the two RBF wells. The coordinate of the RBF1 is 14˚40'29.0" North and 75˚46'38.6" East and the coordinate of the RBF2 is 14˚40'27.8"North and 75˚46'32.9"East. The soil is obtained from a depth of meter, as the bit pierces into a ground surface. A soil collected is conveyed to a Soil Laboratory to study its characteristics. The methodology followed for the present study is shown in Figure 2.
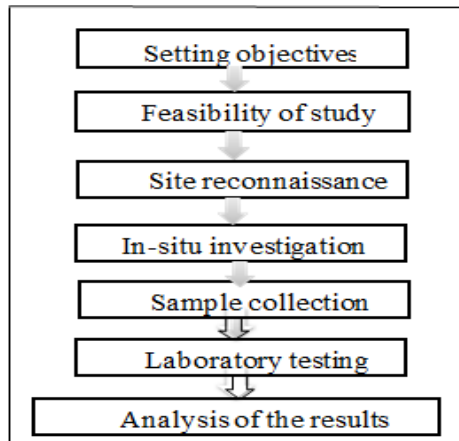

Fig. 2. Work Flow

4   Experimental Results

(A) Sieve Analysis: The grain size or sieve analysis of soil sample helps to know about its texture based on which the porosity and permeability of soil sample depends. Tables 1, 2, & 3 indicate the values of Grain Size Analysis Test.

Table 1. Grain Size test results of sample (1)

Sieve size in mm	Mass of soil retained (g)	% mass retained	Cumulative % retained	% finer
4.75	140	14	14	86
2	270	27	41	59
1	328	32.8	73.8	26.2
0.6	108	10.8	84.6	15.4
0.3	97	9.7	94.3	5.7

0.15	38	3.8	98.1	1.9
0.075	10	1	99.1	0.9
pan	9	0.9	100	0

The shape of distribution curve of grain-size of soil shows the degree of uniformity of soil. A steeper curve shows more uniform soil. Hence, the distribution curve is also known as 'uniformity curve'. Quantitatively speaking, the soil uniformity is defined by its "Coefficient of Uniformity" Cu.

$C_u = \frac{D_{60}}{D_{10}}$ Where, D60 = 60% finer size. And D10=10% finer size. Soil is considered to be very uniform, if Cu< 5; it is of medium uniformity, if Cu = 5 to 15; and it is very non-uniform or well-graded, if Cu> 15. One more factor which signifies a shape of distribution curve is "Coefficient of Curvature", CC, is given by: $C_c = \frac{(D_{30})^2}{D_{10} \cdot D_{60}}$ (2) Where, D30 = 30% finer size. Cc must be 1 to 3 for a well-graded soil. On an average for, Sands Cu = 10 to 20, Silts Cu = 2 to 4. The soil sample 1, depth ranging from 3.5-5.0 m had D10 = 0.408 mm, D30 = 1.084 mm, and D60 = 2.605 mm, Cu = 5.061 and Cc = 1.394, according to Indian standard code of practice (IS: 460-1962) the soil is categorized as Poorly graded sands and gravelly sands, little or no fines. The particle size distribution curve of this soil is displayed in Figure3.

Fig. 3. Grain Size distribution curve of Sample (1), Fig 4. Grain Size Distribution Curve of Sample 2

Table 2. Grain Size analysis test for sample (2)

sieve size in mm	Mass of soil retained (g)	% mass retained	Cumulative% retained	% finer
4.75	236	23.6	23.6	76.4
2	222	22.2	45.8	54.2
1	187	18.7	64.5	35.5
0.6	84	8.4	72.9	27.1
0.3	156	15.6	88.5	11.5
0.15	62	6.2	94.7	5.3
0.075	8	0.8	95.5	4.5
pan	44	4.4	99.9	0.1

The soil sample 2 had D_{10} = 0.254 mm, D_{30} = 0.716 mm, and D_{60} = 2.507 mm, C_u = 9.870 and C_c = 0.8050, according to IS: 460-1962 the soil is categorized as Poorly graded sands and gravelly sands, little or no fines. The particle size distribution curve of this soil is displayed in figure 4.
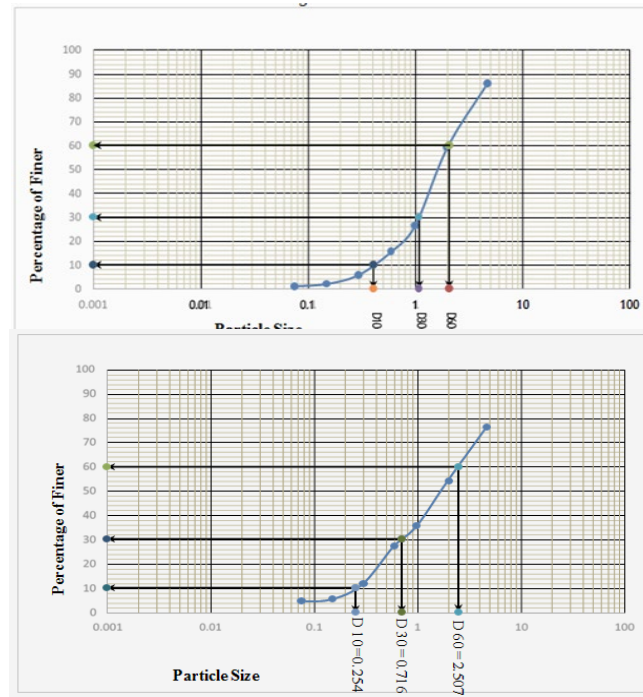
Table 3. Grain Size Analysis Test for Sample 3

sieve size in mm	Mass of soil retained (g)	% mass retained	Cumulative % retained	% finer
4.75	370	37	37	63
2	214	21.4	58.4	41.6
1	148	14.8	73.2	26.8
0.6	68	6.8	80	20
0.3	76	7.6	87.6	12.4
0.15	64	6.4	94	6
0.075	14	1.4	95.4	4.6
pan	46	4.6	100	0

The soil sample 3 had D_{10} = 0.231 mm, D_{30} = 1.378 mm, and D_{60} = 4.208 mm, C_u = 18.2164 and C_c = 1.953, according to IS: 460-1962 the soil is categorized as Poorly graded sands and gravelly sands, little or no fines. The particle size distribution curve of this soil is displayed in Figure 5.
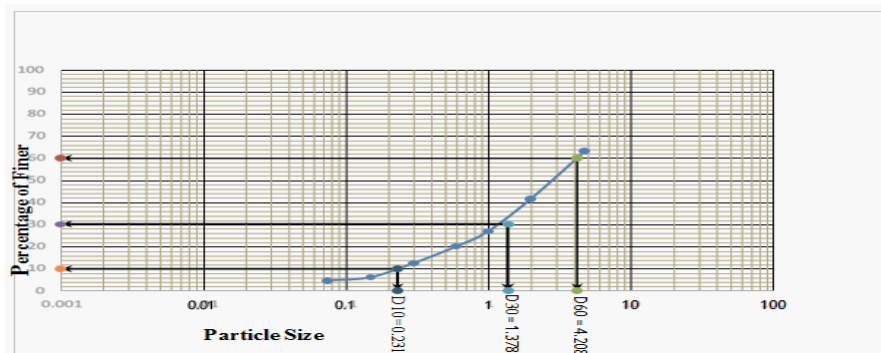

Fig. 5. Grain Size Distribution Curve of sample 3

From the grain size analysis of sample 1, 2 & 3, it is found that soil grains are dominated with gravel and sand particles. This shows that soil is more suitable for RBF with high porosity.

(B) Permeability Test: The permeability of the soil sample defines its capacity to transmit water through its pore spaces. Table 4 indicates the typical values of K for various types of soils. And tables 5, 6, & 7 shows the results of test conducted using permeameter.

Table 4. Typical Values of K in cm/sec

Sl. No	Soil type	Value of K cm/Sec	Relative permeability
1	Clean gravel	1.0 and greater	High
2	Sand (mixture)	1×10^{-2} to 5×10^{-2}	Medium
3	Fine Sand	5×10^{-2} to 1×10^{-3}	Low
4	Silty sand	2×10^{-3} to 1×10^{-4}	Very Low
5	Clay	1×10^{-6} and smaller	Impervious

Table 5. Permeability Test for Sample 1

Sl. No	Head of Water	Volume of water collected	Time	Discharge per sec	Hydraulic gradient	Permeability in cm/Sec	Avg. permeability
1	222	270	15	18	18.5	0.0123	
2	222	400	25	16	18.5	0.0110	1.16×10^{-3}
3	222	495	30	16.5	18.5	0.0113	

Table 6. Permeability Test for Sample 2

Sl. No	Head of Water	Volume of water collected	Time	Discharge per sec	Hydraulic gradient	Permeability in cm/Sec	Avg. permeability

	222	165	15	11	18.5	0.00757	
1							7.67×10^{-3}
2	222	290	25	11.6	18.5	0.00798	
3	222	325	30	10.83333	18.5	0.00746	

From table 5 it is found that the average value of permeability as $1.16 \times 10\text{-}3$cm/sec, which falls in the category of very low permeability (table 4). From table 6 it is found that the average value of permeability as $7.67 \times 10\text{-}3$cm/Sec, which falls in the category of medium permeability (table 4).

Table 7. Permeability Test for Sample 3

Sl. No	Head of Water	Volume of water collected	Time	Discharge per sec	Hydraulic gradient	Permeability in cm/Sec	Avg. permeability
1	222	95	15	6.33333	18.5	0.00436	
2	222	130	25	5.2	18.5	0.00358	3.87×10^{-3}
3	222	160	30	5.33333	18.5	0.00367	

From table 7 it is found that the average value of permeability as $3.87 \times 10\text{-}3$cm/Sec, which falls in the category of low permeability (table 4). Sample 2 has highest permeability of $7.67 \times 10\text{-}3$ cm/Sec out of the three values. Hence sample 2 is found to be suitable for RBF to get high yield of water.

5   Conclusions

Following conclusions drawn from the experimental study on different soil samples collected from various parts of selected site. The grain size analysis of sample 1, 2 & 3showed that soil consist of gravel and sand. The permeability of soil sample1, 2,&3 are 1.16×10^{-3}cm/sec, 7.67×10^{-3}cm/sec, and 3.87×10^{-3}cm/sec respectively. The maximum permeability of soil at site 1 is 7.67×10^{-3} cm/sec. The soil which has the maximum permeability (sample 2) is more likely to be suitable for the River Bank Filtration application.

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