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GEOTEXTILE FILTER FOR EARTHEN DAMS-LABORATORY STUDY

Satyendra Mittal[1] and Ms. Anamika[2]

ABSTRACT

Filters are essential component of large earth dams. They are provided to lower the phreatic surface within the dam. For the filter to function properly, filter has to satisfy few engineering requirements. In projects where granular material is not readily available or where the appropriate aggregate sizes can not be obtained in sufficient quantities, the design and construction of filter can be a tedious and uneconomical task. In such ssituation, geotextile filter constitute an attractive solution and can be used as a replacement to conventional granular filter.

This study has been made on functional comparison of conventional granular filter with innovative geotextile filter. An attempt has been made to design a suitable granular filter for the given base soil (Sand) and then analyse the dam model with granular filter as well as geotextile filter. Experimental test results have been validated by analytical study of the dam model carried out using SEEP/W – GeoStudio 2007 software.

Keywords: *Earthen dam model, Granular Filter , Geotextile Filter, SEEP/W*

INTRODUCTION

Filtes and the drains associated with them help in lowering the phreatic surface within the dam and forbid water from transpiring through the downstream side of the slope, where flow could provoke erosion that may put at risk the integrity of the whole structure. Satisfying the filter requirements in the earthen dams is of primary importance. Projects, where granular material is not available at or around site or where the aggregate of appropriate sizes cannot be obtained in adequate quantities, the design and construction of filter can be a tedious and uneconomic task. Graded filter can be either expensive to purchase or difficult to obtain. And it may take a long time also to install it. It may thus lead to compromising its filtration efficiency. In such situations, geotextile filter may provide an attractive solution and can be used as a replacement to granular filter.Recent ban by Supreme court in India(and may be in other countries also) on sand quarrying, the price of sand have gone up because of higher costs involved in manual mining of sand. In the present scenario Geotextile filtration system equipped with reliable design consideration can be of much help, serving as a cost effective solution without compromising the safety of hydraulic structures (Mittal, 2014, FEMA 2011, Koerner et al.,1984, Sato et al.,1986, Zobernberg, 2012, Giroud, 1996).

DESIGN OF GRANULAR FILTER

Cedergren (1977) suggested that the filter material should satisfy two conflicting requirements: 1. Piping Requirement: The pore spaces in drains and filters that are in contact with erodible soils and rocks must be small enough to prevent particles from being washed in or through them. 2. Permeability Requirement: The pore spaces in drains and filters must be large enough to impart sufficient permeability to permit seepage to escape freely and thus provide a high degree of control over seepage forces and hydrostatic pressures. Grading of the protective filter can be related to that of the soil being protected by the following relationships (Ranjan & Rao, 2002)

$$\frac{(D_{15})\text{ Filter}}{(D_{85})\text{ Base Soil}} < 5 \qquad \ldots\ldots\ldots\ldots(1)$$

$$4 < \frac{(D_{15})\text{ Filter}}{(D_{15})\text{ Base Soil}} < 20 \qquad \ldots\ldots\ldots\ldots(2)$$

$$\frac{(D_{50})\text{ Filter}}{(D_{50})\text{ Base Soil}} < 25 \qquad \ldots\ldots\ldots\ldots(3)$$

Few Other Specifications for Granular Filter (Mittal, 2013) are as follows:

(i) $(D_{15})_{Filter} \geq 5\ (D_{15})_{\text{Base Soil}}$ or 0.1 mm whichever is higher .... (4)

(ii) $(D_{15})_{Filter} \leq 9\ (D_{85})_{\text{Base Soil}}$ or 0.2 mm whichever is higher .... (5)

(iii) $(D_{15})_{Filter} \leq 0.7$ .... (6)

(iv) $(D_{15})_{Filter} \leq 4\ (D_{85})_{\text{Base Soil}}$ .... (7)

(v) Material passing 75 μ (micron) should not exceed 5% .... (8)

(vi) Limits of $(D_{10})_{Filter}$ and $(D_{90})_{Filter}$ for preventing segregation are here as under (Table1):

Table 1: Limits of (D_{10}) Filter And (D_{90}) Filter for Preventing Segregation

(D_{10})Filter (Min) (mm)	**(D_{90})Filter (Max) (mm)**
< 0.5	20
0.5 – 1.0	25
1 – 2	30
2 – 5	40
5 – 10	50
10 – 50	60

1. *Associate Professor, Deptt. of Civil Engineering, IIT Roorkee, India,*

2. *Assistant Professor, Noida Institute of Technology, Noida, India, E-mail: satyendramittal@gmail.com,miss.anamika@gmail.com*

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MODEL TESTS

Tests On Earthen Dam Model – Without Any Filter

Earthen dam model was constructed using fine sand as base soil and was tested for the seepage flow through the downstream side of the cross-section in the absence of filter. Schematic of cross sectional profile of the model and the model constructed in the laboratory has been shown in Figs. 1 and 2 respectively. The earthen dam model was prepared in a steel tank with following dimensions:

Height = 850 mm, Length = 3000 mm, Width = 635 mm. The upstream side of the embankment was filled with water upto a height of 0.5m (Fig. 2). A constant head was maintained at the upstream side by providing an outlet for water in the tank at 0.5m height. At the downstream side whole width of the tank was sealed with a brick wall in which a steel pipe was provided as an outlet to collect the water seeping through downstream side which was measured with time (Fig. 3). More details are given elsewhere (Anamika, 2015).

Thus, the dam section had following dimensions :

Cross-sectional area = 1.02 m^2 , Slope angle (θ) = 26.56,

Volume of Earthen Embankment = 1.02 x 0.635 = 0.6477 m^3. The

weight of sand required for the construction of the model embankment was = 1.53 x 0.6477 x 1000 = 990.981 kg. Density of the embankment (for 65% relative density) = 15.3 kN/m^3 . The grain size analysis of the base soil, with which dam model was made, is shown in Fig. 4. On the basis of the results of the grain size

analysis , the other soil parameters were:

$(D_{85})_{Base\ Soil}$ = 320 μ, $(D_{50})_{Base\ Soil}$ = 220 μ, $(D_{15})_{Base\ Soil}$ = 180 μ,

$(D_{10})_{Base\ Soil}$ = 172 μ

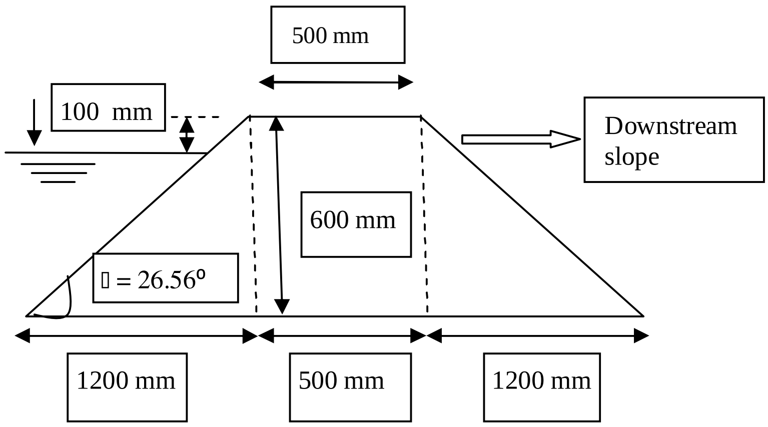


Fig. 1: Cross-Section of Earthen Dam Model without Any Filter

Fig. 2: Filling of Water at the Upstream Side

Fig. 3: Collecting the Water Seeped Through Earthen Dam Cross- Section

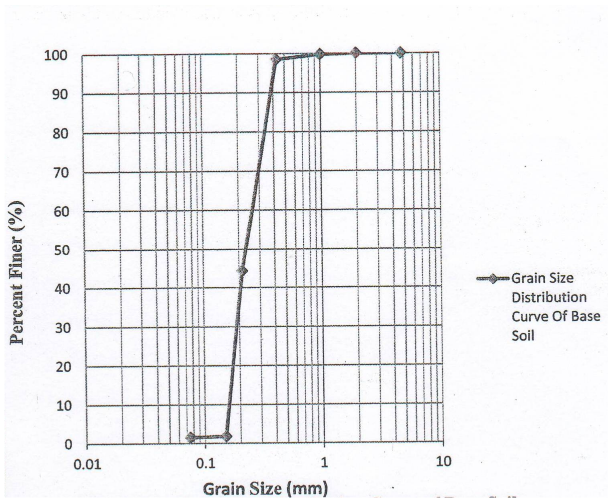
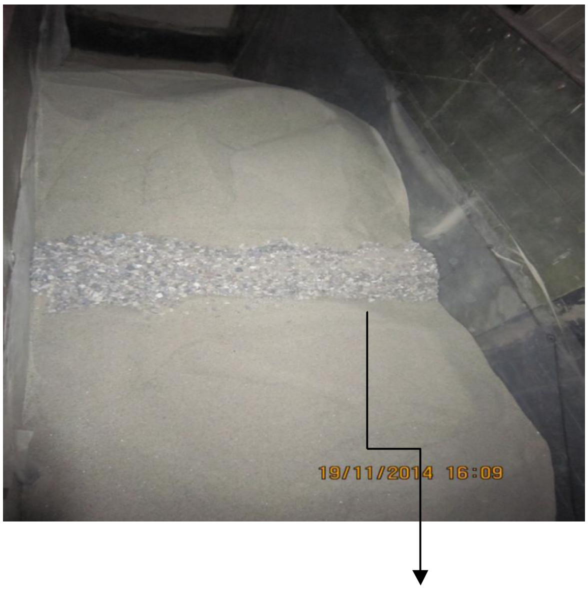


Fig. 4 : GSD of base soil



Chimney Drain

Fig. 5: Construction of Chimney Filter

Test on Earthen Dam Model With Base Soil As Fine Sand And Filter As Conventional Granular Filter

The test was conducted on earthen dam model using fine sand as base soil (Fig.4) and granular filter, as per conventional practices (Fig. 5). Its fabrication was also done as described in para 3.1 above. In this model tests, filter had to be made as per conventional laws (Eqns. 1-3). Thus, following

Tests On Earthen Dam Model With Geotextile Filter

In these model tests, earthen dam model was constructed with the same sand as base soil (Fig. 4) and was tested for the seepage flow through the downstream side of the cross-section through the geotextile filter. This geotextile filter is illustrated in Fig. 7, and its schematic layout is shown in Fig. 8.

Giroud (1996) has proposed soil retention criteria for steady state flow conditions through dam bodies. The same has been followed in present study also. According to that-

$O_{95} < 2\ C'u\ .D_{50}$, i.e. $O_{95} < 498\ \mu$ .... (9)

Minimum Allowable Geotextile permeability using permeability criteria is $kg > Is.\ ks$ (After Giroud, 1998) .... (10)

Where,

Is = Hydraulic gradient(= 2 for dam toe drain, 3-10 for dam clay cores)

ks = Soil hydraulic conductivity.

For the present base soil, the soil permeability, determined from falling head permeability method was 6.03×10^{-2} cm/sec. Hence, based on present model test, $kg > 6.03 \times 10^{-2}$ cm/sec. Using these two conditions only, the non woven geotextile sample had been selected for model tests. The properties of geotextile (Fig. 9) selected for model tests were determined in IIT Roorkee labs. The same are as follows :

Apparent Opening Size (O_{95}) = 250 microns

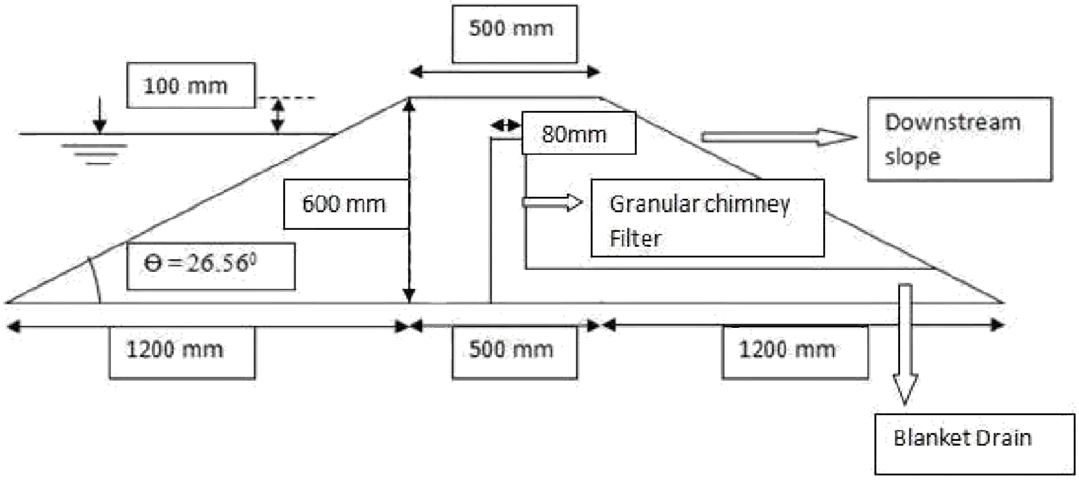


Fig. 6: Schematic of Model Test with Granular Filter

properties of the granular filter were adopted in present study:

$(D_{15})_{Filter} = 425\ \mu$, $(D_{50})_{Filter} = 4.75$ mm, $(D_{90})_{Filter} = 6.3$ mm

In this model, as shown in Fig. 6, a chimney filter and a horizontal blanket drain were also provided with granular filter soil material, with specifications, as mentioned above. With this model, no failure of downstream slope was observed. The test results obtained from this model are shown in tabular form in the end of this paper.

Coeff. of permeability = 3.4×10^{-3} cm/sec

Thickness = 1.4 mm, Permittivity = $0.0223\ sec^{-1}$

The results of the tests are summarised in tabular form, and are presented in the end of this paper. It was observed that geotextile filter performed very effectively as a filter material, as it qualified with the required permeability of the filter material (Cedergren, 1977).

The results obtained from laboratory models were validated with the software SEEP/W also.

Fig. 7: Model Test Showing Geotextile Filter, As A Replacement To Conventional Granular Filter

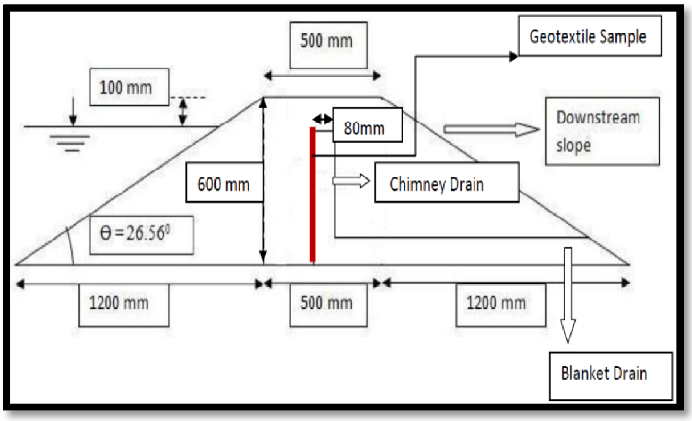


Fig. 8: Schematic of Earthen Dam Model With Geotextile As Filter

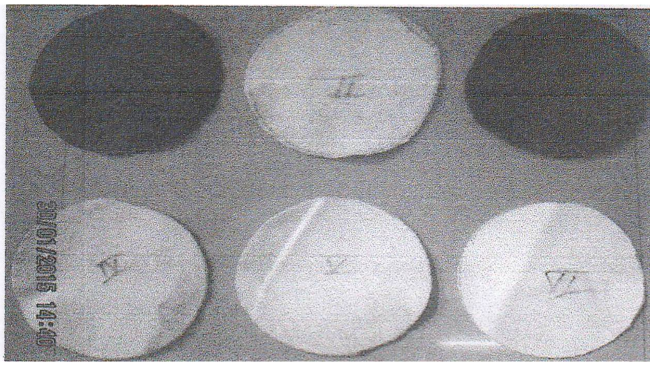


Fig. 9: Various Samples of Geotextile Used For Permeability Tests. Finally, Sample No. VI Was Used For Model Tests

ANALYTICAL STUDY ON SEEP/W: WITHOUT ANY FILTER

Results of all the experimental model setups were also validated with the help of SEEP/W – GeoStudio 2007 software. SEEP/W is a numerical model that can mathematically simulate the real physical process of water flowing through a particulate medium. Numerical modeling is purely mathematical and in this sense is very different than scaled physical modeling in the laboratory or full-scaled field modeling. First of all, layout of the problem was drawn. Then various materials with their hydraulic properties were defined. After defining the material, these were assigned to respective regions. Then boundary conditions were defined and assigned to specific nodes, lines or regions. Then mesh properties were defined and finally the problem was solved using solve analyses tool.

Firstly layout of the model was drawn for no filter case. Material property of the base soil i.e. fine sand was defined and then this material was assigned to the respective region drawn. Boundary conditions applied include:

- Total head at upstream side below the water level is constant

- At toe point pressure head is zero

- Downstream side is the potential seepage face

After defining the mesh properties, problem was solved and the total head contour and the total flux passing through the section was obtained. Thereafter problem definition and the total head contour for all the cases were drawn (Anamika, 2015). One representative such mesh is shown in Fig. 10 for geotextile filter.

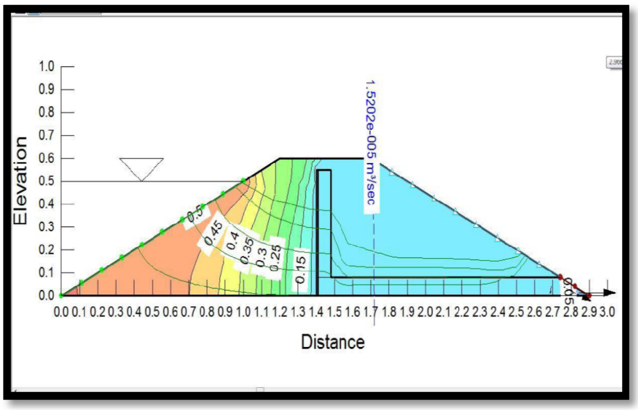


Fig. 10: Total Head Contours Obtained with Geotextile Filter case byusing SEEP/W – GeoStudio 2007 software

RESULTS

In each model test, flow rate was measured ,i.e. the particular quantity of water coming out of the filter material and the time taken for that. The details of the results are presented elsewhere (Anamika, 2015). The summary of the results is given in Table 2 below.

Table 2: Summary of Model and Analytical Test Results

Parameters	Without any filter	With Granular Filter	With Geotextile Filter
Time taken by water to appear at downstream slope (hrs)	3.5	2.5	2.75
Seepage rate per unit width (m^3/sec)	4.24×10^{-6}	15.87×10^{-6}	11.81×10^{-6}

Failure of down-stream slope	Yes	No	No
Seepage rate per unit width obtained from SEEP/W analysis (m^3/sec)	4.43 x 10^{-6}	11.43 x 10^{-6}	11.42 x 10^{-6}

CONCLUSIONS

Conclusions drawn from this study are summarized as below:

1) Time taken by the water to seep through the dam model cross-section for various cases was observed in the following order,

No Filter > Geotextile Filter > Granular Filter

2) Seepage rate through the dam model cross-section for various cases was observed in the following order,

Geotextile Filter ≈ Granular Filter > No Filter

3) Seepage rate through the dam model for various cases obtained by

analytical analysis using SEEP/W – Geo Studio 2007 software was found to be comparable with the model test results obtained from the model tests conducted in the lab.

4) Geotextile filter design based upon above study forms a coherent criteria that allows safe design of geotextile filter. Since seepage rate for granular filter and geotextile filter was observed to be approximately same, these two can be used at site.

5) The sites, where granular material is not available in adequate quantity, geotextile filter can be adopted with the same output.

6) Installation of geotextile filter involves less manual labour and there is no risk of segregation of material during placement as compared to pure granular filter.

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