Analysis and Design of Ferrocement Cut Off Trench in Earthen Dam: A Case Study of Bham Dam

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Abstract

Cut off trench (COT) in the section of earthen dam is made up with impervious layer of black cotton soil. Large amount of fertile land is invested to maintain the impervious layer in cut off zone. This paper presents analyis and design of ferrocement cut off trench. Geo Studio 2012 software is used for analytical studies of cut off trench and various soil investigations are done with experimental investigation. A case study of Bham Dam located in Igatpuri, Nashik (India) is analyzed for investigations and design of ferrocement cut off trench. By designing the cutoff trench with ferrocement, thousands of tons of black cotton soil can be saved. It takes thousands of years to form the black cotton soil. The result shows that in case of Bham Dam, approximately 2.78 lakh ton of fertile soil can be saved by adopting ferrocement COT in earthen dam.

Keywords: Cut off Trench, Earthen Dam, Seepage Analysis, Geostudio.

1. INTRODUCTION

Cut off trench which is an underground seepage barrier is a conventional method for reducing the seepage through earthen dam foundation. The selection of material of COT is based impervious properties and black cotton soil is preferred as most suitable material since it has very low permeability

Black cotton soil is the earth's fragile skin that anchors all life on Earth. It is comprised of countless species that create a dynamic and complex ecosystem and is among the most precious resources to humans. Half of the topsoil on the planet has been lost in the last 150 years. To serve the agriculture needs, solution on the loss of fertile land has to find out.

Approximately 2.78 lakh ton of fertile soil is required for Bham Dam located in Igatpuri, Nashik (India) only in cut off trench zone. The solution of this problem can be explored by using the innovative technology. To have the impervious layer in foundation of the earthen dam cut off trench, Ferrocement technology is tried. Ferrocement is a composite of rich cement mortar and mesh reinforcement. Since the wire mesh is stronger in tension and makes the matrix of mortar as perfectly homogenous, the cut off trench with ferrocement is best solution to make the impervious layer in dam foundation.

In present study, the case of Bham dam is considered. It is an earthen dam and is under construction. It is situated in the catchment of *Bham river* located in Kaluste village of Igatpuri in Nasik district (India). The dam is 1500 m in the length and 31.78 m in height with average depth 13 m of cut off trench in dam foundation.

The hydraulic study of Bham dam at Chainage of 700 m along the length of dam is carried out, which includes soil studies and permeability studies for hearting and casing of the dam. This chainage is approximate mid chainage of the dam in the length of 1500 m. With the input of experimental works, detailed study of seepage analysis is carried out in GeoStudio 2012 software to get various pressure heads and total head for knowing the behavior of phreatic line.

2. SOIL INVESTIGATION

For the detailed study of seepage analysis and to know the behavior of phreatic line in the GeoStudio 2012 software, inputs of coefficient of permeability and Grain size analysis (D60 and D10) are required. Hence, in this study coefficient of permeability and Grain size analysis are calculated at CH700 m by constant head test and sieve analysis, respectively. The coefficient of permeability and grain size are calculated for both casing and hearting zone. For this experimental investigation, the different soil samples are taken from CH700 m in the casing and hearting zone of Bham Dam. The coefficients of permeability for these samples are 6.145 X 10^{-3} and 3.781 X 10^{-4} for casing and hearting, respectively. The grain size analysis shows that the Particle size in mm for Casing and Hearting are 0.55(D10), 4.15(D60), 0.4(D10) and 5.5(D60), respectively. Moisture content of soil samples is also calculated in soil investigation. The samples were taken from actual Dam site. The moisture content was used as one of the input parameters for the Geo Studio 2012 software to perform seepage analysis. The moisture content for samples at Chainage700 m was 36.76 % for casing and that of for hearting was 14.45%.

3. HYDRAULIC ANALYSIS BY GEOSTUDIO 2012

GeoStudio 2012 is the analysis software used to perform various analyses related to earthen dam like seepage analysis, stability analysis, stress and deformation analysis, earthquake analysis, thermal analysis, contaminant analysis and air flow analysis. GeoStudio SEEP/W 2012 is used for the seepage analysis of Bham dam. The cross-section of dam at Chainage 700 m is considered for the analysis and soil properties at this Chainage are provided as input to the software. Parameters of Bham Dam used for the analysis are as follows:

Type of Dam: Earthen
Height: 31.78 m   Width: 263.16 m
Length: 1500 m   Free board: 2.55 m
Average depth of Foundation: 6.65m
Average depth of Cut off Trench: 6 m

The cross-sectional profile of Bham Dam modeled in Geo Studio software at CH700, is shown in Figure 1

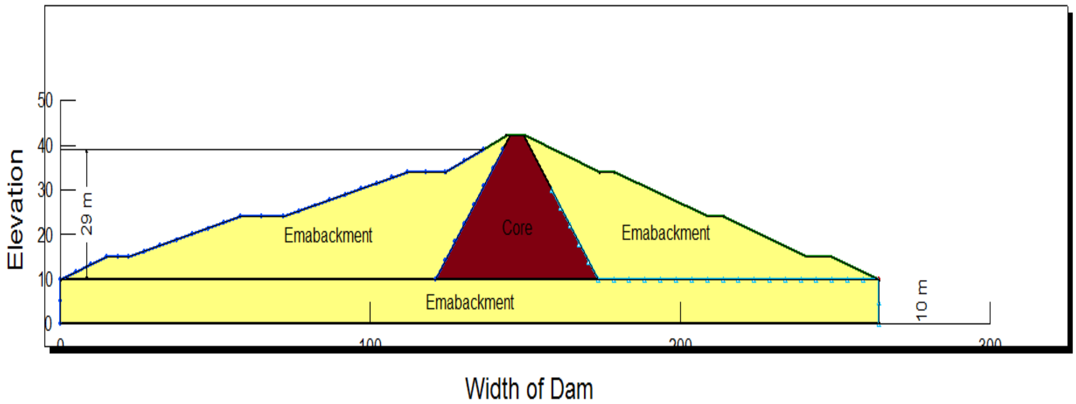

Figure 1: Total Head variation at CH130 (Total Head: 29m)

From this modeling of Bham dam in GeoStudio 2012, various results are obtained which include the Total Head, Pressure Head and Hydraulic conductivity through earthen dam. Table1 given below shows the various results of Bham dam at CH700 m.

Table 1 Results of seepage analysis at Ch.700 m

Sr. No.	Parameters	Results from GeoStudio
1	Water Flux (m³/sec)	9.561341e-005
2	X-Velocity Magnitude (m/sec)	1.4628577e-007
3	Y-Velocity Magnitude (m/sec)	1.4349074e-007
4	Total Head (m)	39
5	Pore-Water Pressure (kPa)	284.403
6	Pressure Head (m)	29

Figures 2, 3, and 4 show Total Head, Pressure Head and Hydraulic conductivity, respectively.

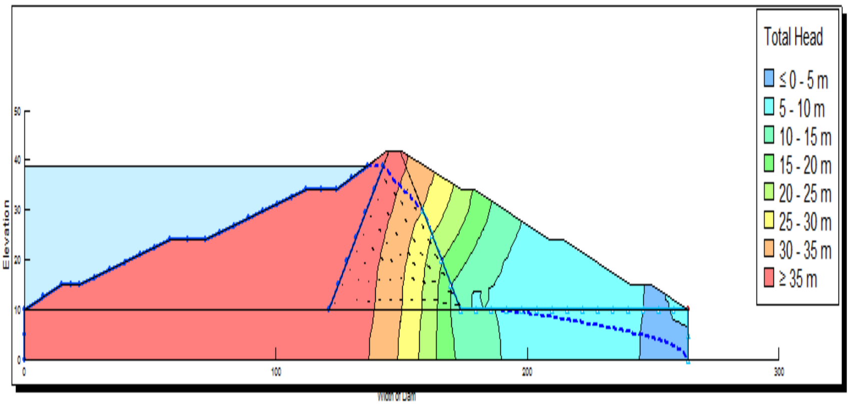

Figure 2: Total head variation at Ch.700 m (Total head :39m)

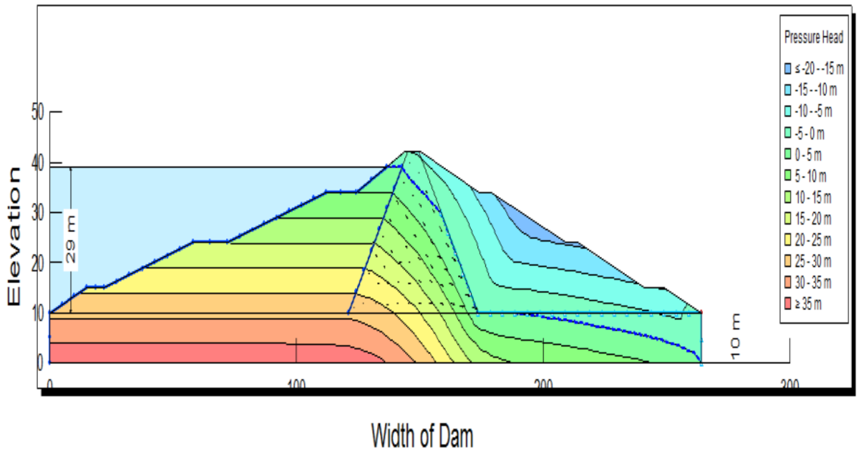

Figure 3: Pressure head variation at Ch.700 m (Total head :29m)

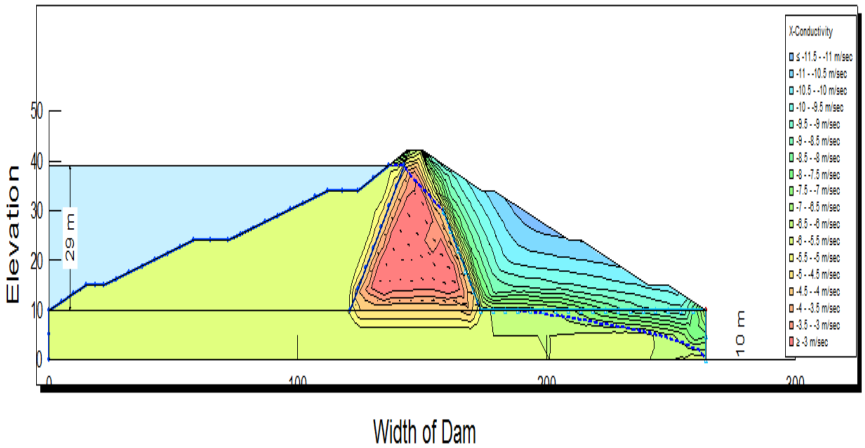

Figure 4: Hydraulic Conductivity at CH700 (Conductivity: 1.4628577e-007)

From the seepage analysis, the worst pressure conditions were determined. The results of pressures are 29 m total head of water and 6.112 kg/cm^2 as saturated soil pressure.

4. FERROCEMENT PANELCASTING

Ferrocement cut off trench panels were cast using the matrix of 1: 2 cement mortar and welded and chicken mesh reinforcement. The number of mesh layers were calculated using ACI Code of ferrocement, ACI 549R.The details of design data of ferrocement COT panels is shown in Table 2.

Table 2: Design data of ferrocement COT panels.

Sr. No.	Parameters	Specification
1.	Cut-off trench panels size	1 m x 1 m
2	Skeletal steel	8 mm @ 300 mm c/c
3	Type of Wire mesh	Welded mesh and Chicken mesh
4	Mortar proportions	1:2
5	Water to cement ratio	0.5
6	Thickness of panels	25 mm
7	No of wire mesh layers	2 (min.)
8	No. of panels	6 no’s

The panels were cast, cured and tested in loading frame for the flexural loading. Table 3 shows the results of flexural test.

It is clearly seen from the results of flexural strength test results that, the average flexural strength of cut off trench panels with welded mesh have more strength than that of panels with the chicken mesh. But results can be carefully noted as both of panels have flexural strength more than the total pressure obtained from the analytical calculations and worst loading cases. The average flexural strength of both of the panels is compared with the total pressure of 0.6 N/mm^2 which is obtained from analytical solution of case II. Total pressure of second worst loading case is calculated by considering saturated unit weight of soil for the overall depth of 32 m from the foundation of the dam. The obtained flexural strength of the welded mesh panels is more than the chicken mesh wire because the strength of the ferrocement material depends on the specific surface area of the wire mesh and welded wire mesh provides more specific surface area than the chicken wire mesh.

Table 3: Flexural tests results of ferrocement cut off trench panels

Sr. No.	Sample Designation	Maximum pressure from worst loading cases	Flexural strength (N/mm^2)	Avg. flexural strength (N/mm^2)
1	Panel 1 (Chicken mesh)	Total pressure = **0.6 N/mm^2**(Case II: Saturated soil pressure for depth of 32 m)	1.47	**1.28**
2	Panel 2 (Chicken mesh)		0.92	
3	Panel 3 (Chicken mesh)		1.45	
4	Panel 4 (Welded mesh)		1.90	**1.68**
5	Panel 5 (Welded mesh)		1.45	
6	Panel 6 (Welded mesh)		1.71	

5. COEFFICIENT OF PERMEABILITY:

The coefficient of permeability for ferrocement cutoff trench panel core for welded mesh core and chicken mesh core is determined by falling head test. Coefficient of permeability of the ferrocement panel core is calculated by measuring the discharge per unit time. The homogenous nature of mortar and wire mesh together is not allowing any flow of water to seep through it. Hence no flow of water is obtained in the 24 hours.

6. CONCLUSIONS

From the obtained results it is clear that the ferrocement cut off trench is the possible solution for the cut off trench in earthen dam. Ferrocement cut off trench panels can be provided instead of traditional cut off trenches, as it has passed for flexural as well as permeability test. This will facilitate to avoid the use of black cotton soil in COT portion of an earthen dam in the quest of preserving the natural resources for sustainable development.

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