iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** V **Month of publication:** May 2022

DOI: https://doi.org/10.22214/ijraset.2022.42312

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

Seepage Analysis of Core Section of Jhuj Dam

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Abstract: ***Zoned type Earthen dams are the type of Rolled fill Earthen dam because the soil is compacted by mechanical rollers in thin layers of 20-30 cm having central impervious core surrounded by shell as pervious material. These dams made since early days of civilization and constitute to be the most common type, because it is generally built of locally available soils proved to be most economical. The soil used in earthen dam are suspectable to seepage through the body of dam due to their permeability. Due to seepage soil gets reduces its strength and failures of dam may occurs. Past studies on earthen dam failures concluded that about 30% of dam failed due to seepage. An impervious central core is used in zoned type earthen dam to reduce the seepage quantity through the body of the dam and protects against the seepage failure of dam like piping and sloughing. Earthen dams are vulnerable to failures due to seepage that take place in the core since all soils are pervious to some extent. One of the best ways to control seepage problem in earthen dam is by using proper impervious soil for core section which provides the water tightness to flow through it. Thus, this paper analyses the usage of locally available soils with different combinations with central impervious vertical core and to study the seepage discharge by using Darcy law. The results obtained from the study is compared with actual seepage data obtained with existing soil in central core.***
Keywords: Impervious core, Permeability and Seepage, Smear effects, Phreatic line, Flow net

I. INTRODUCTION

Earthen dams have been constructed since the ancient time and the most common and economic type of dams. This is because earth fill dams can be constructed using locally available materials in the natural state with minimum processing without much skilled supervision and can be suitable for all type of foundation. In India Earth fill dams are likely to continue to be prevalent because a large number of sites with potential for water resources development are not favourable for concrete structures. It serves all the purposes such as storage, detention or diversion; but basically, they are built for storage purpose. Seepage is the flow of water through the body and the foundation of earthen dam due to difference in head.

Seepage is unavoidable in case of all the earth fill dams. If seepage is controlled and limited it does not cause any damages. However uncontrolled seepage through the dam body or its foundation may lead failures of dam. Past studies shows that they have 30% contribution towards the failure of dam.

Many earth fill dams are vulnerable to failures due to seepage problems that take place in the core since all soils are pervious to a smaller or larger extent.

One of the ways to control seepage problem in earthen dam is by using proper materials for core section since the core section of earthen dam provides impermeable barrier within the body of the dam. The principal purposes of design of earthen dam are to make water tight to obtain required imperviousness of the core zone. The interest of present study is focused towards zone type earth dams with central impervious core.

Because, the pervious outer zones enclose, support and protect the impervious core and also its advantages will lead to economics in cost of construction. The purpose of core section of the earthen dam is to arrest the seepage of water from upstream side to downstream side. Hence, selection of core material for proper functioning of dam is a great challenge. The study will concentrate on seepage as earthen dam always impound water in it. Based on literature review, it is observed that limited studies regarding core section of earthen dam using design mix in its construction were done. In view of this observation, an experimental work was undertaken and the present paper is the outcome of such a work. The objective of this paper is to study the influence of different materials and their combinations in the core section to compute seepage and slope stability and to evaluate how the length of horizontal filter affects the seepage discharges through the core section of the dam.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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II. STUDY AREA AND DATA COLLECTION

In this study, Jhuj Dam located across the Kaveri River near vansda village, Gujarat, India is selected to determine the seepage rate passing through its core section. The dam is zoned type earthen dam having c/s as shown in figure 1.

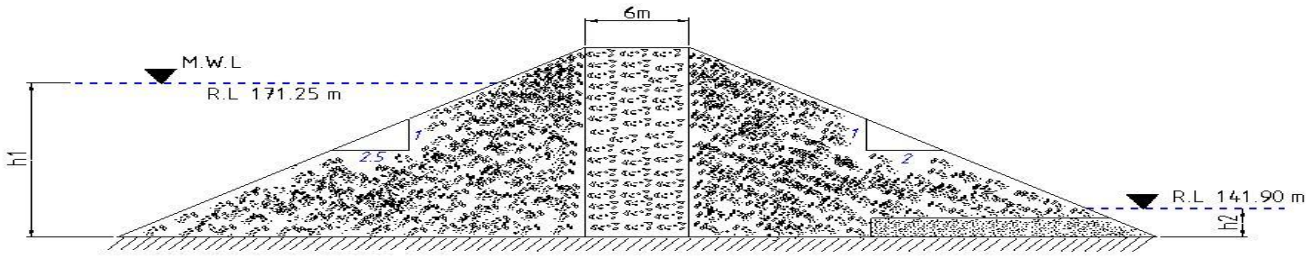


Figure No.1 c/s of Jhuj Dam

The other details of study area in the table no.1

Table No: 1 Details of study area

Name of the scheme	: Jhuj irrigation scheme
Location	: Across Kaveri River
Type of the dam	: Rolled filled zoned type
Length of the dam	: 693 m
Height of the dam	: 36.75 m
Free board	: 3.25 m
Top of the dam R.L	: 174.50 m
Full reservoir level	: R.L 167.50 m
Maximum water level	: R.L 171.25 m
Low water level	: R.L 147.00 m
Tail water level	: R.L 141.90 m

Location co-ordinate of study area given in the table no.2

Table No: 2 Co-ordinates of study area

Latitude	: 20^0 43' 30" N.
Longitude	: 73^0 24' 15" E.
Toposheet No	: 46 H/6

Location view of study area given in figure no.2

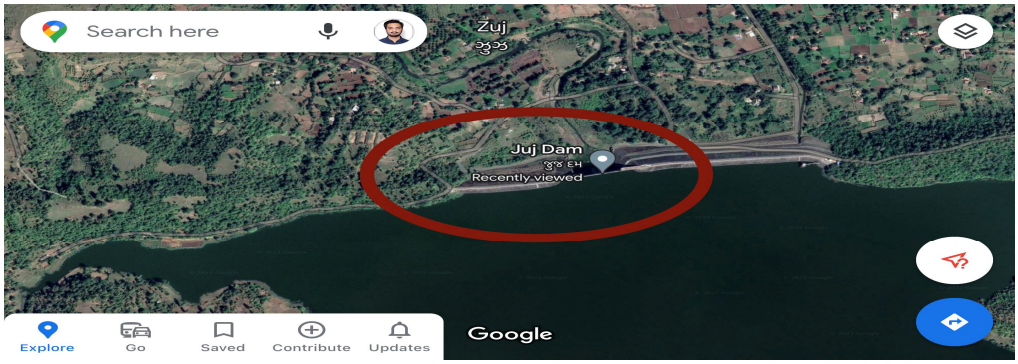


Figure No. 2 Google map view of study area

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The seepage data collected from the year 2012 to 2017 from the body of dam is wright in the table no. 3 below.

Table No: 3 Seepage data from the dam

Year	Seepage rate (m^3/sec per metre)
2012	1.668×10^{-6}
2014	1.587×10^{-6}
2015	1.635×10^{-6}
2016	1.723×10^{-6}
2017	1.532×10^{-6}

III. EXPERIMENTAL PROGRAM

Three soil samples S1, S2 and S3 are collected within the radius of 4 km area is collected and the samples are classified based on IS-classification system. For that sieve analysis, liquid limit test and plastic limit test is performed in the laboratory. All the data observed from the above test is describe in the table no. 4 below.

Table No: 4 Seepage data from the dam

Soil sample	% Retain on 4.75 mm IS sieve	% Passing through 4.75 mm IS sieve	WL	WP	IP	A-Line =0.73(WL-20)	Atterberg limit w.r.t A-line in plasticity chart	IP w.r.t 4 and 7	Classified soil symbol
S1	52%	48%	35%	13%	22%	16.06	Above	> 7	SC
S2	34%	66%	48%	20%	28%	21.84	Above	> 7	CL
S3	61%	39%	25%	18%	7%	3.65	Below	< 4	SM

Hence, SC= clayey silt, CL=low compressible soil, SM=silty sand

Now, all the three soil samples are mixed by weight in the different proportion as mention in the table no.5 below and named it as MP1, MP2 and MP3. (MP= Mixed Proportion)

Table No: 5 Seepage data from the dam

Sr. no	Mixes soil sample	% Of soil sample		
		S1	S2	S3
1	MP_1	33%	33%	33%
2	MP_2	25%	25%	50%
3	MP_3	25%	50%	25%

To determine the coefficient of permeability of mixed soil MP_1, MP_2 and MP_3, falling head permeability test is performed in the laboratory which yields the following observation table no. 6

Table No: 6 Seepage data from the dam

Sr. no	Mixes soil sample	Coefficient of permeability (cm/sec)	Notation of permeability (K_{MP})
1	MP_1	3.8×10^{-5}	K_{MP1}
2	MP_2	2.35×10^{-5}	K_{MP2}
3	MP_3	1.94×10^{-5}	K_{MP3}

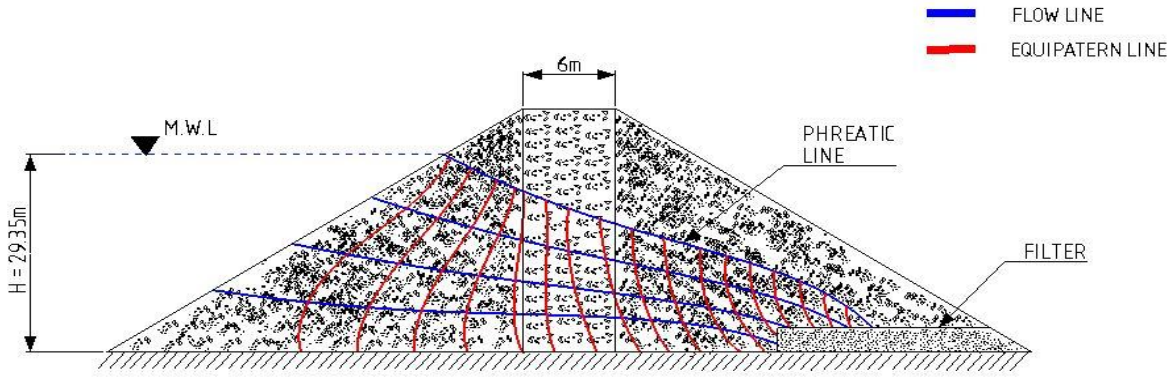
From the above table it is obvious that the mixed soil sample MP_3 is having the least permeability $K_{MP3}=1.94 \times 10^{-5}$cm per seconds. So, mixed sample MP_3 is selected in the Darcy law to calculate the seepage rate.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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IV. RESULTS AND DISCUSSION

To calculate the seepage rate, a flow net is plotted in the c/s of Jhuj Dam. There are four numbers of flow line, N_f and seventeen numbers of equipotential line, N_d. The head causing flow in the maximum water level is, h=29.35 m.



Hence total seepage discharge passing through the entire flow net is given by Darcy law is,

$$q = K\,H\,\frac{N_f}{N_d}$$

$$q = 1.94 \text{ x } 10^{-7} \text{ x } 29.35 \text{ x } \frac{4}{17}$$

$$q = 1.33974 \text{ x } 10^{-6}\ m^3/\text{sec per metre}$$

From the above calculation it is obvious that, mixing of proper mixed gradation of soil for the design of core section of earthen dam, the seepage rate can be reduced up to certain extent. It is due to the soil particles are get deposited and re-arrange in the densest packing state which provide the water tightness against the seepage in earthen dam. Also, it is proved to be economical in case of large earthen dam whare the requirement of material is large and unavailability of suitable impervious material.

V. CONCLUSION

Based on the results obtained from laboratory experiments, proposed geometry of cross section of zoned dam and their corresponding seepage discharges for mixed soil materials, the following conclusions are drawn.

An attempt of mixing three different materials in the design mix proves to be good agreement after arriving at the test results. Usage of design mix of soil fraction reduces the permeability value due to the densest packing of soil fraction which is an essential property for a core material.

In the present proposed section of dam, the core height is limited till the freeboard and is considered sufficient. This idea saves the material used for core and leads to economy in construction. The quantity of discharge calculated by considering the values of the flow net will give identical results which is adopted for practical case. For that the number of flow line and equipotential line is taken as 4 and 17 respectively. Based on the experiment data of soil permeability and head causing flow the seepage discharge per metre is obtained based on analysis of flow net and Darcy law is 1.339 x $10^{-6}m^3$/sec. The data collected in the year of 2016, the seepage recorded per metre in the maximum reservoir level condition is 1.723 x 10^{-6} m^3/sec, which is 22.28% higher than existing seepage rate. Accordingly, seepage discharge rate per metre for the year of 2012, 2013, 2014, 2015 and 2017 is .688 x 10^{-6}, 1.587 x 10^{-6}, 1.635 x 10^{-6} and 1.532 m^3/sec respectively which can be lower by the 20.29%, 15.62%, 18.10%12.59% respectively. So, it is concluded that by using the soil of different mixed proportion in the core section of Jhuj dam, on and average 14.82% seepage rate per metre discharge can be reduced.

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VI. ACKNOWLAGEMENT

I would like to take this opportunity to express my since and deep gratitude towards my guide **Nayan P. Soni (Asst. Professor),** SSGEC, Bhavnagar. I also would like to convey sincere thanks to Dr.V.M. Patel (Head of Department), and entire Civil Engineering Department of SSGEC, Bhavnagar for providing all the support in compilation of this dissertation report. I would like to convey my very special thanks to Prof. C.P. Ladavia, Assistant professor in civil engineering department, C.K Pithawalla College of Engineering and Technology, Surat., who always encouraged me and asked me to come out with new search and idea every time.

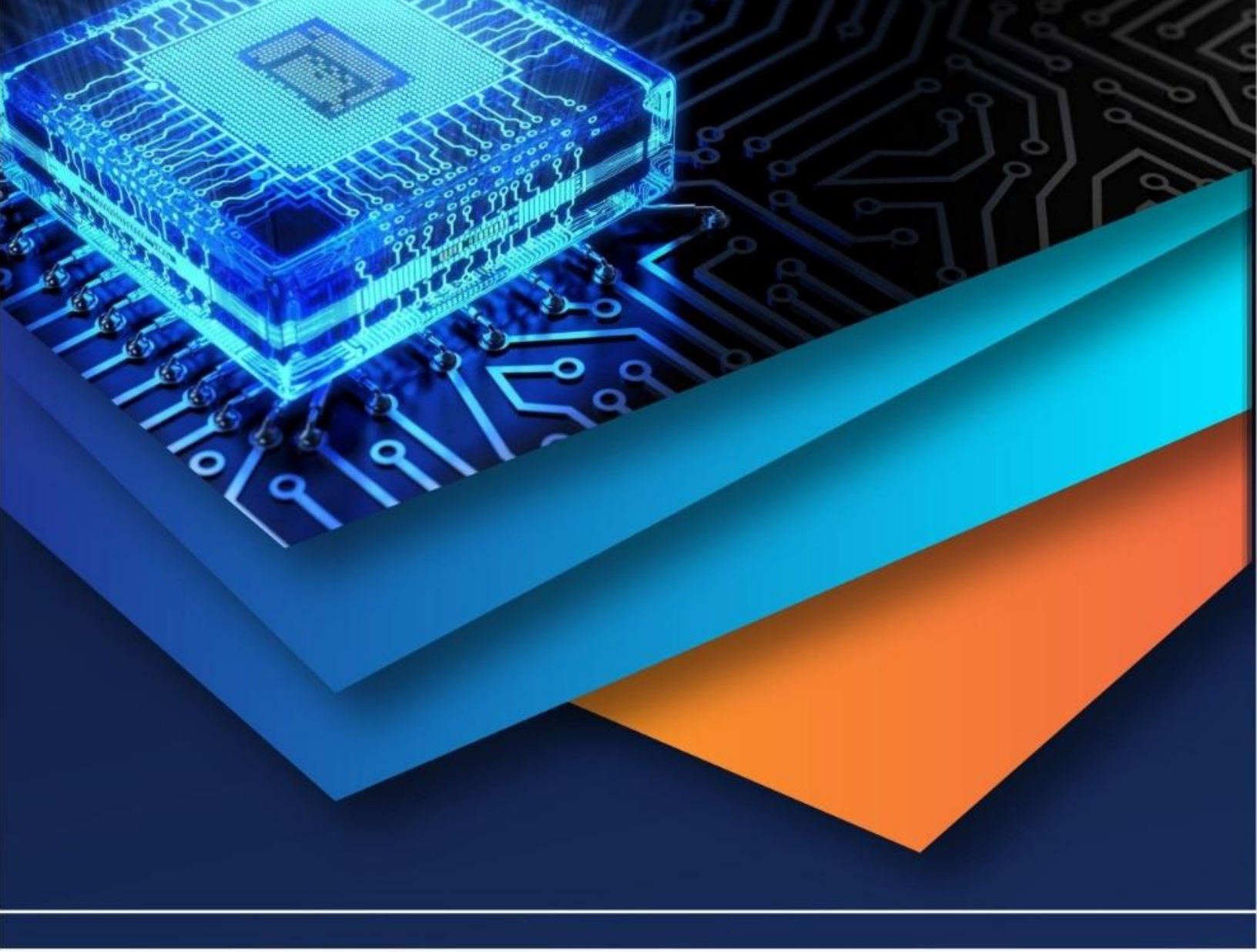
I would like to convey my very special thanks to the whole team of Mattest Engineering Services, Surat to allow me for the experiments in their laboratory. My special thanks to my friends, Mr. Mahindra J. Sosa who assisted me in the experiment program carried out for this research work. I am also thankful to, my elder brother Mr. Gunjesh N. Vasoya (Design Engineer, Xylem Water Solutions & Water Technology) who help me for drafting task in this research work and always available for me in tough times and encouraged me to keep on trying till I reach to the desired result.

My special thanks to my Family, who give their support, encouragement and prayers, which keep me on my toes to work hard and to give my best. I express my sincere thanks to those who directly and indirectly extended help during the research work.

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