DESIGN AND ANALYSIS OF EARTH DAM FOR A RESERVOIR

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ABSTRACT

This work shows the results obtained from the design of the Earth Dam for a reservoir of 1.087 TMC Capacity. This water retaining earth dam design includes the design of main dam and a surplus weir. To begin, the basic design data which includes the class of the water retaining structures, characteristic water level and fetch length are determined. The work continues with the presentation of the exact location, and the different structures that constitute the earth dam. The dam slope and crest which make up the dam body are also presented followed by their sizing. In addition a study of the seepage-proofing soil and filling material of the dam body is done.

INTRODUCTION

Irrigation is the artificial application of water to the soil usually for assisting in growing crops. It is critical, yet a vital input of agriculture production process and pivotal to agricultural, social, and economic growth of nation. Civilizations have been dependent on development of irrigated agriculture to provide agrarian basis of a society and to enhance the security of people. Along with bless irrigation also brought the inherent attachments of several problems like salinity and water logging. Civilizations have risen and fallen with the growth and decline of their irrigation systems, while others have maintained sustainable irrigation for thousands of years. Understanding history of irrigation development helps in augmenting knowledge about the traditional systems many of which are equally relevant in today's context. Further, there are several lessons which we may learn from the past experience. Such lessons which enrich our design and management options must be explored.

Irrigation has two primary objectives

- To supply essential moisture for plant growth, this includes transport of essential nutrients
- To leach or dilute salts in soil.

Besides this irrigation provides number of side benefits, such as cooling the soil and atmosphere to create more favorable environment for crop growth, Irrigation supplements the supply of water received from precipitation and other types of atmospheric water, flood waters and ground water.

Irrigation has acquired increasing importance in agriculture the world over. From just 8 million hectares (Mha) in 1800, irrigated area across the world increased fivefold to 40 Mha (13.4 Mha in India) in 1900, to 100 M Ha in 1950 and to just over 255 M Ha in 1995. With almost one fifth of that area, India has the highest irrigated land in the world today.

History of Irrigation Development in the World

- Archaeological investigation has identified evidence of irrigation in Mesopotamia and Egypt as far back as the 6th millennium BCE, where barley was grown in areas where the natural rainfall was insufficient to support such a crop.
- In the 'Zana' Valley of the Andes Mountains in Peru, archaeologists found remains of three irrigation canals radiocarbon dated from the 4th millennium BCE, the 3rd millennium BCE and the 9th century CE. These canals are the earliest record of irrigation in the New World.
- The Indus Valley Civilization in Pakistan and North India (from 2600 BCE) also had an early canal irrigation system. Large scale agriculture was practiced and an extensive network of canals was used for the purpose of irrigation. Sophisticated irrigation and storage systems were developed, including the reservoirs built at Girnar in 3000 BCE.
- There is evidence of the ancient Egyptian pharaoh Amenemhet - III in the twelfth dynasty (about 1800 BCE) using the natural lake of the Fayûm as a reservoir to store surpluses of water for use during the dry seasons, as the lake swelled annually as caused by the annual flooding of the Nile.
- The Qanats, developed in ancient Persia in about 800 BCE, are among the oldest known irrigation methods still in use today. They are now found in Asia, the Middle East and North Africa. The system comprises a network of vertical wells and gently sloping tunnels driven into the sides of cliffs and steep hills to tap groundwater.
- The Noria, a water wheel with clay pots around the rim powered by the flow of the stream (or by animals where the water source was still), was first brought into use at about this time, by Roman settlers in North Africa. By 150 BCE pots were fitted with valves to allow smoother filling as they were forced into the water.
- The irrigation works of ancient Sri Lanka, the earliest dating from about 300 BCE, in the reign of King Pandukabhaya and under continuous development for the next thousand years, were one of the most complex irrigation systems of the ancient world. In addition to underground canals, the Sinhalese were the first to build completely artificial reservoirs to store water. The system was extensively restored and further extended during the reign of King Parakrama Bahu (1153 – 1186 CE).
- In the Szechwan region ancient China the Dujiangyan Irrigation System was built in 250 BCE to irrigate a large area and it still supplies water today.
- In fifteenth century Korea the world's first water gauge (woo ryang gyae) was discovered in 1441 CE. The inventor was Jang Young Sil, a

Korean engineer of the Chosen Dynasty, under the active direction of the King, Se Jong. It was installed in irrigation tanks as part of a nationwide system to measure and collect rainfall for agricultural applications. With this instrument, planners and farmers could make better use of the information gathered in the survey.

History of Irrigation Development in India

Ancient Indian writers and ancient Indian scriptures have made references to wells, canals, tanks and dams. These irrigation technologies were in the form of small and minor works, which could be operated by small households to irrigate small patches of land. In the south, perennial irrigation may have begun with construction of the Grand Anicut by the Cholas as early as second century to provide irrigation from the Cauvery River. The entire landscape in the central and southern India is studded with numerous irrigation tanks which have been traced back to many centuries before the beginning of the Christian era. In northern India also there are a number of small canals in the upper valleys of rivers which are very old.

DESIGN PROCEEDURE

Out of the available methods for freeboard computations, assistance has been derived from T. Saville's method, which is widely used for freeboard computations of embankment dams.

The freeboard should be calculated for following conditions:

1) Normal freeboard that is at FRL.

2) Minimum freeboard that is at MWL.

The freeboard which gives the highest requirement of TBL (Top Bund Level) should finally be adopted.

Normal Freeboard

While calculating normal freeboard at FRL, full wind velocity should be adopted.

The design wave height (I&) be taken as 1.67 times the significant wave height (&).

Normal freeboard should not be less than 2.0 m.

Minimum Freeboard

While calculating minimum freeboard at MWL, halt to two third wind velocity should be adopted. The lower values may he adopted in regions where maximum wind velocities occur during the period when water level in the reservoir is at or below FRL. This freeboard should be subject to a minimum of 1.5 m. The design wave height (Ho) is taker, as I.27 times the significant wave height (HS).

MINIMUM FREEBOARD AT MWL

For obtaining minimum freeboard at MWL Half to two third wind velocities on land and effective fetch at MWL may be adopted for different calculations using above steps. Check, if minimum freeboard is less than 1.5 m and if so, provide at least 1 .5 m Freeboard.

COMPONENTS OF EARTH AND ROCKFILL DAMS

An earth dam generally consists of the following components

a) Cut-off,
b) Core,
c) Casing,
d) Internal drainage system,
e) Slope protection, and
f) Surface drainage

BASIC DESIGN REQUIREMENTS:
Earth dam - The basic requirements for design of earth dam are to ensure

(a) Safety against overtopping,
(b) Stability, and
(c) Safety against internal erosion,

Overtopping - Sufficient spillway and outlet capacity should be provided to prevent overtopping of earth embankment during and after construction. The freeboard should be sufficient to prevent overtopping by waves and should take into account the settlement of embankment and foundation.

Freeboard for wave run up on slope shall be provided in accordance with the provisions contained in ' Indian Standard recommendations for freeboard requirements in earth dams.

Analysis should be made for computing the settlement of the embankment and of the foundations in order to determine extra freeboard to be provided as settlement allowance. For unyielding foundation, the amount of settlement for the embankment should be restricted to 1 percent of the height of dam. For compressible foundations, the settlement should be computed based on laboratory test results and should be provided by increasing the height of dam correspondingly. Longitudinal camber should be provided on the top of dam along the dam axis to provide for settlement. The camber varies from zero height at the abutments to maximum at the central section in the valley where maximum settlement is anticipated.

METHODS OF ANALYSIS
The methods of analyzing the slope stability depending upon the profile of failure surface

a) Circular arc method, and

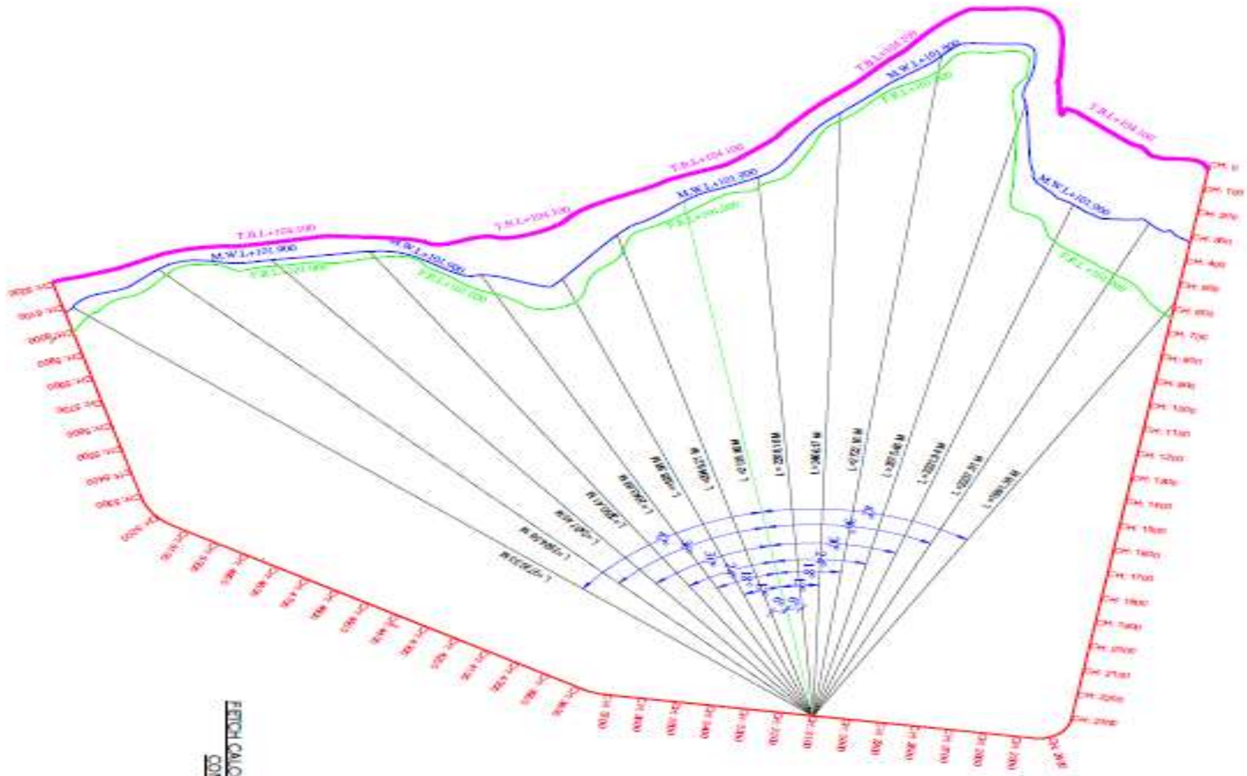
b) Sliding wedge method.

CIRCULAR ARC METHOD
In this method of analysis the surface of rupture is assumed as cylindrical or in the cross section by an arc of a circle. This method, also known as Swedish or Slip Circle method, is generally applicable for analysing slopes of homogenous earth dams and dams resting on thick deposits of fine grained materials.

SLIDING WEDGE METHOD
The sliding wedge method of analysis is generally applicable in the circumstances where it appears that the failure surface may be best approximated by series of planes rather than a smooth continuous curve as for the method of circular arc. the following two circumstances:

a) Where one or more horizontal layers of weak soil exist in the upper part of the foundation, and

b) Where the foundation consists of hard stratum through which failure is not anticipated and dam resting on it has a core of fine-grained soil with relatively large shells of dense granular material.



FETCH CALCULATION IN MWL CONDITION

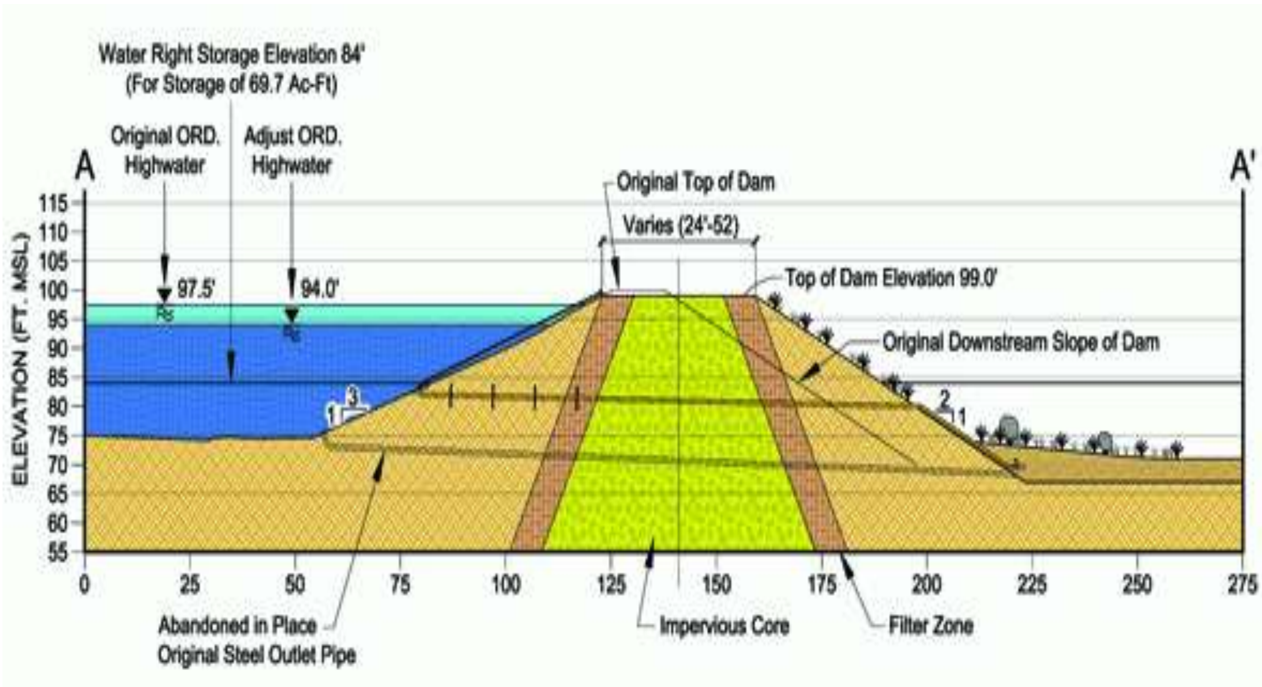
Hydralic Particulars of Reservior

1	F.R.L	+ 101.000
2	M.W.L	+ 101.900
3	T.B.L	+ 104.100
4	BUND LENGTH IN KM	6.200
5	LATITUDE	14.°39'.42.0''
6	LONGITUDE	79°24'.13.1"

LEGEND

DESCRIPTION	
PROPOSED BUND	(red line)
F.R.L	(green line)
M.W.L	(blue line)
T.B.L	(magenta line)

Note:–All Dimension & levels are in metres



DENSITY & SHEAR PARAMETERS OF SOILS CONSIDERED IN DESIGN
FOR 18.625 M HEIGHT SECTION

As per the given report, the following propertis of soils are considered in the stability analysis.

EMBANKMENT SOILS: **HOMOGENEOUS SOILS**

Type of soil		=	SC	
Sample no from APERL report		=	Lab reference: SML/3/159/2013 - 14	
OMC %		=	12.20%	
100% Saturation content	W	=	15.20%	
Max drydensity MDD at OMC	γ_d	=	1899	Kg/m^3
	Cohesion 'C'	=	2500	Kg/m^2
	ϕ	=	28	Degrees
γ_{Sat} =	$\gamma_d (1 + W / 100)$	=	1899 (1 + 0.152)	
		=	2188	Kg/m^3
	Cohesion 'C'	=	1500	Kg/m^2
	ϕ	=	26	Degrees
γ_{Sub} =	$\gamma_{Sat} - \gamma_W$	=	2188 - 1000	
		=	1188	Kg/m^3
	Cohesion 'C'	=	1500	Kg/m^2
	ϕ	=	26	Degrees

Foundation soils:

Type of soil		=	SC or GC
Sample no from APERL report		=	Lab reference: RSTL/32/2014 - 15
FMC %		=	14.90%
100% Saturation content	W	=	20.60%
Max drydensity MDD at OMC	γ_d	=	1720 Kg/m^3
	Cohesion 'C'	=	1500 Kg/m^2
	ϕ	=	23 Degrees
γ_{Sat} = γ_d (1 + W / 100)		=	1720 (1 + 0.206)
		=	2074 Kg/m^3
	Cohesion 'C'	=	500 Kg/m^2
	ϕ	=	18 Degrees
γ_{Sub} = γ_{Sat} - γ_W		=	2074 - 1000
		=	1074 Kg/m^3
	Cohesion 'C'	=	500 Kg/m^2
	ϕ	=	18 Degrees

Rock toe:

γ_{Sub}	=	1200 Kg/m^3
Cohesion 'C'	=	0 Kg/m^2
ϕ	=	40 Degrees

CONCLUSION

The objective of this work was to design the earth dam for a reservoir of 1.087 TMC The simplified methodology used in the design of the Earth dam was based on Indian standard codes.

Detailed studies of the basic design data and analysis enabled us determining the stability of the dam to be used and the material requirements for the seepage proofing soil and the dam body structure.

Through evaluation and calculations, it was concluded that the earth dam is a silty soils. The dam crest elevation is 104.100m, the dam crest width is 6.00m and the maximum dam height is 18.625m. Riprap is provided on the upstream side of the dam body and turfing is provided on downstream side for slope protection. Rock Toe is provided at the dam foot for drainage on the slope. Cut off trench is provided in the dam foundation for seepage proofing

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