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Feasibility Study of Bellary Nala Irrigation Project

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ABSTRACT

Gravity dams are solid concrete structures that maintain their stability against design loads from the geometric shape, mass and strength of the concrete. The purposes of dam construction may include navigation, flood damage reduction, hydroelectric power generation, fish and wildlife enhancement, water quality, water supply, and recreation. The design and evaluation of concrete gravity dam for earthquake loading must be based on appropriate criteria that reflect both the desired level of safety and the choice of the design and evaluation procedures. In India, the entire country is divided into 4 seismic zones, depending upon the severity of the earthquake intensity. Thus, the main aim of this study is to design high concrete gravity dams based on the U.S.B.R. recommendations in seismic zone II of India, for varying horizontal earthquake intensities from 0.10 g - 0.30 g with 0.05 g increment to take into account the uncertainty and severity of earthquake intensities and constant other design loads, and to analyze its stability and stress conditions using analytical 2D gravity method. The vertical, principal and shear stresses are also obtained. Feasibility studies are carried out to design a concrete gravity dam for horizontal earthquake intensity greater than 0.30 g without changing other loads and or dimension of the dam and keeping provision for drainage gallery to reduce the uplift pressure significantly.

KEYWORDS: *Comparison; Concrete Gravity Dam; Dam Failure; Design; Earthquake Intensity, Stability and Stress*

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I. INTRODUCTION

DAM

A hydraulic structure (fully impervious or fairly impervious) constructed across a river to store water on its upstream side forming reservoir, which can be used at later stages. They are classified based on their use, materials of construction and hydraulic design.

Classification based on use-

[1] **Storage dam** – it is the most general type of dam to impound water on upstream side during high flow in rivers and used during the period of deficiency. They are constructed for various purposes like irrigation, power generation, water supply etc. Storage dam maybe constructed of gravity, earth, rock fill and arch dam.

[2] **Diversion dam** – these dams simply raise the water level in the river on its upstream side and provide sufficient head for diverting water into ditches, canals and other conveyance system. It is of smaller height and no water is stored on upstream side. Ex: weirs and barrages.

[3] **Detention dam** – they are constructed to store water during floods and release it gradually when flood recedes. This will reduce the flood damage on downstream side. In some, situations, the water detained on the upstream side in not released and held as long as possible. This detained water seeps through banks and foundation strata, which help in increasing the water level of ground.

[4] **Coffer dam** – a coffer dam is a temporary dam constructed to exclude water from a specific area.

[5] **Debris dam –** a debris dam is constructed to catch and retain debris such as sand, gravel, silt and drift wood flowing along with water in the river.

Classification based on hydraulic design –

[1] **Non- over flow dam** – no over floe section is provided and crest of the dam will be higher than maximum water level. Construction materials used are concrete, earth, rock fill, masonry.

[2] **Over flow dam** – it consists of an over flow section which discharges surplus water over its crest flowing on downstream face. It is usually made of concrete so that the dam material is not eroded.

Classification based on material –

1. Rigid dams – they are constructed of rigid material such as masonry, concrete, steel or timber. They are further classified as

A.Solid masonry or concrete gravity dam
B.Arched masonry or concrete dam.
C.Concrete bitterness dam.
D.Steel dam.
E.Timber dam.

Non rigid dam – non rigid materials such as earth and rock fill are used in these dams. Common types are

a) Earth dam.
b) Rock fill dam.
c) Combined earth and rock fill dam.

Classification based on structural behavior –

[1] **Gravity dam** – a gravity dam is a masonry or concrete dam which resists the forces exerted upon it by its own weight. Its cross – section is approximately triangular in shape.

[2] **Arch dam** – an arch dam is a curved masonry or concrete dam, convex upstream, which resists the forces exerted upon it, mainly by arch action.

[3] **Buttress dam** – a Buttress dam consists of a water retaining sloping membrane or deck on the upstream which is supported by the series of the buttress which is generally in the form of equally based triangular reinforced concrete or masonry walls.

[4] **Embankment dam** – an Embankment dam in a non – rigid dam, which resists the forces exerted upon it mainly by its shear strength.

Classification based on size: The overall size classification for the dam would be greater of that indicated by either of the following two parameters:

classification	**Gross storage**	**Hydraulic Head**
Small	Between 0.5 and 10 million m3	Between 7.5 and 12m
Intermediate	Between 10 and 60 million m3	Between 12 and 30m
Large	Greater than 60 million m3	Greater than 30 m

II. LITERATURE REVIEW

Literature referred during the preparation of this thesis is mainly regarding the earthquake intensities, effects of different shapes of galleries like rectangle, square, triangle and horse shoe. The research papers also defines optimal top width and optimal shape of concrete gravity dam.

A.S. Shirkande V. B. Dawari describes the effect of openings is usually neglected in design of dam but it is well thought out when openings are large. Large openings generate critical zones for tensile stresses in dam. The work reported here comprise of analysis of dam with large openings. The limitations considered are size and shape of large openings. Three models like without gallery, dam with regular size galleries and dam with large inspection gallery are considered for comparing the effect of the size variation of inspection gallery on dam. The effect of different shapes of galleries like rectangular, square, circular and horse shoe on stresses in dam is studied for various locations. Overall square shaped inspection gallery gives minimum stress around gallery. Due to large openings, there is increase in stresses around the openings and in the dam.

It has been detected that large openings in the dam induce higher stresses in the vicinity of them. In some cases, these openings have contributed up to fifteen to seventeen percent increase in stresses. The variation according to different shapes is five to ten percent. However, square galleries show less increase in stresses as compared to other shapes.

Farzin Salmasi study based on the design of a gravity dam is achieved through an interactive process concerning a preliminary layout of the structure followed by a stability and stress analysis. This study presents a method to define the optimal top width of gravity dam with genetic algorithm. To solve the optimization task (minimize the cost of the dam), an optimization routine based on genetic algorithms (GAs) was executed into an Excel spreadsheet. It was found to implement well and GA parameters were optimized in a parametric study. Using the parameters found in the parametric study, the top width of gravity dam optimization was performed and compared to a gradient-based optimization method (classic method). The accuracy of the results was within close proximity. In optimum dam cross section, the ratio of dam base to dam height is almost equal to 0.85, and ratio of dam top width to dam height is almost equal to 0.13. The computerized methodology may provide the help for computation of the optimal top width for a wide range of height of a gravity dam.
In this study the design of gravity dam corresponding to the optimal top width can be approved for any required height of the dam. The obtained design is the most economical and the safest in which no tension is created anywhere in the dam section.

III. STUDY AREA

3.1. The river

Bellary nala originates near Yellur village in Belgaum taluk and is a tributary to Markandeya River. The length of the nala up to its confluence with Markandeya river is 57 Km (36 miles). The Markandeya River is a tributary of Ghataprabha River and in turn Ghataprabha River is a tributary of Krishna River. The catchment area of Bellary nala up to proposed dam site is 253.82 Sq. Kms
.

3.2. History

The areas of Belgaum district through which the tributary of Krishna River flows, are in rain shadow areas, where in annual rainfall is 740mm and is unevenly distributed. Even though the lands are fertile, they are subjected to frequently occurring drought and scarcity conditions. In the absence of any other mineral resources, and industrial development, the local population is dependent on rain fed agriculture. With the uncertain rainfall, the farmers are depending on subsistence farming, resulting in low per capita income leading to poverty and low contribution of GDP.In order to overcome the frequently occurring drought and scarcity, it was proposed to construct an irrigation project across Bellary nala which is flowing in this region. Earlier, it was proposed to construct a dam near Hudli village in Belgaum taluk and to feed water to Markandeya Right Bank Canal (ongoing Project) by a link canal of 3 Km by gravity flow. Since the Bellary nala carries the Belgaum city sewage water throughout the year, it was proposed to run the canal of Bellary nala project, parallel to Markandeya Right Bank Canal up to the length of 90 Km where the Markandeya Right Bank Canal ends and further up to 106.656 Km, to totally irrigate the lands coming under villages of Belgaum, Gokak, Bailahongal and Soudatti talukas of Belgaum District.

3.3. Project proposal

It is proposed to construct Bellary nala project which provides, irrigation facilities to the lands of Belgaum District coming under Belgaum, Gokak, Bailahongal and Soudatti talukas. Bellary nala carries the Belgaum city sewage water throughout the year in addition to the rainfall run-off in the rainy season. The Nala water is unsuitable for potable purposes as per test results, but it is suitable for irrigation purposes. Hence, it was decided not to connect Bellary nala project canal to Markandeya Right Bank Canal, though the topography and feasibility of the project, clearly favors for combining the two projects.
The Bellary nala project consists of, construction of reservoir across the Bellary nala at Karadikolla near Hudli village, Belgaum Taluk, Belgaum District and canal network to supply water for irrigating the lands of, Belgaum, Gokak, Bailahongal and Soudatti talukas.

3.3.1. Location of project

The proposed dam site across Bellary Nala is at Karadikolla near Hudli village, Belgaum Taluk, Belgaum District. The latitude and longitude of the project are 15’58’ N and 74’38’ E respectively.

3.3.2. Access to the project

The proposed dam site is approachable from Hudli village situated on Belgaum – Gokak road about 26 Km from Belgaum city. The project is also accessible through Airway as well as Railway since Belgaum city is having Airport and Railway station.

3.3.3. Area benefited

The command area of this Project is 8,200 Ha, which covers the lands of Belgaum, Gokak, Bailahongal and Soudatti talukas of Belgaum District.

IV. GRAVITY DAMS

The external forces such as water pressure, wave pressure, uplift, silt pressure etc are resisted by the weight of the dam and hence it is called gravity dam. It is constructed of either masonry [small height, ex. KRS] or concrete [large height ex. Hidkal] and may be straight or curved in plan. Most of the gravity dams are solid and hence called solid gravity dam

Forces acting on gravity dam

- **Weight of the dam** – this is the major resisting force, computed by considering 1m length of dam. It is the product of cross – section area of dam section, 1m length and unit weight of dam material.

- **Waterpressure** – it is the major external force, obtained as area of pressure diagram multiplied by length of dam (1m). if the upstream face is vertical, then horizontal pressure fore is
  P = $\frac{1}{2} \Upsilon w\ H2$ acts at $\frac{H}{3}$ from base of dam.
  On the other hand, if the face is inclined, an additional vertical water pressure acts as
  P1 = Area of portion above inclined surface x 1x ϒw. Further, with tail water, P2 and P3 are also considered as
  P2 = $\frac{1}{2} \Upsilon w\ H12$ acts at $\frac{H1}{3}$ from base.
  And P3 = area of portion EFG x 1 x Υ_w

- **Uplift pressure** – the upward pressure exerted by the water that seeps through the body of the dam and through the pores and fissures of the foundation. As per USBR recommendations the intensity of uplift pressure at toe and heel of dam is equal to static water pressure intensity. The drainage gallery provided in the dam relieve the uplift pressure. The uplift pressure diagram is as shown in the diagram 4.1. The uplift pressure force is computed by multiplying area of uplift pressure diagram with length of dam (1m).

Pressure due to earthquake : due to earthquake waves, acceleration are imparted to the foundations and make them to move. To avoid rupture dam should also move along the foundation, which induce inertia force in the body of the dam and sets up stress that move from lower layer to upper elevations. These accelerations are resolved into horizontal and vertical components.

a) Effect of horizontal acceleration -

1. Inertia force in the body of the dam – it acts opposite to the direction of acceleration imparted by earthquake and given by

F = Wα

Acting at centroid of respective portions.

2. Hydrodynamic pressure – the acceleration towards the reservoir induces rise in water pressure which varies parabolic ally as in fig 1.1. The total pressure force

Pe = 0.555 α Υ_w H2

Acting at $\frac{4\ H}{3\ \Pi}$ from the base.

Zanger (1952) presented the formula for computing intensity of pressure derived by electrical analogy assuming water as incompressible. The pressure variation is elliptic – cum – parabolic and intensity at any depth y below MWL is

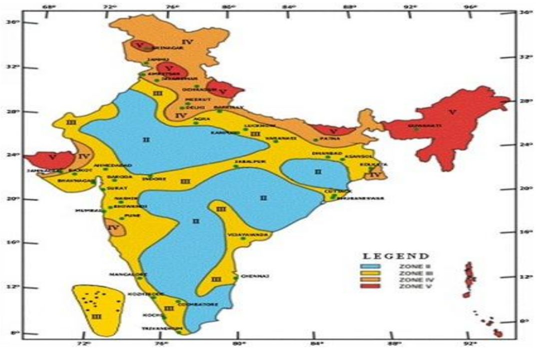
$P_{ey} = C_y\ \alpha\ \Upsilon_w\ y$ Where C_y = dimensionless pressure coefficient at y below free surface

C_m = maximum value of pressure coefficient for a given constant slope = 0.735 $\frac{\theta}{90}$

ϴ = inclination of upstream face with horizontal.

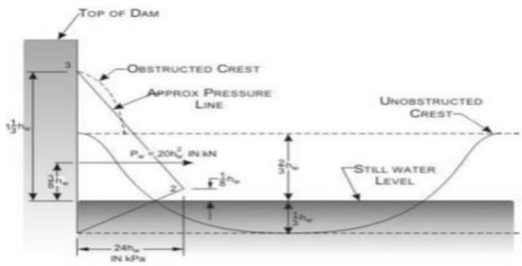
If the upstream side is inclined for a depth smaller than half of height of water storage then upstream face is considered vertical (ϴ = 90) and Cm = 0.735. However, when the upstream face is inclined for more than half

the depth then Θ is obtained by considering modified slope with upstream face connected between MWL and heel point. The pressure variation is considered elliptical – cum – parabolic.
Hence $P_{ey} = 0.726\ p_{ey}\ y$
And the moment about the toe
$M_{ey} = 0.299\ p_{ey}\ y$ Effect of vertical acceleration – Due to vertical acceleration, vertical inertia force (α_W) exerts opposite to that of direction of acceleration. This alerts the weight of the dam.



Ice pressure : it is an important force to be considered when the dam is located in cold region or ay high elevations. The ice formed on the water surface either expands or contracts depending upon the temperature change. When the ice expands it exerts pressure on the upstream face of dam linearly along the length because coefficient of thermal expansion of ice is 5 times that of concrete. The magnitude of ice pressure varies from 2.5 to 15 kg/cm^2. However, an average value of 5 kg/cm^2 is considered under ordinary conditions.

Wave pressure -



Wave height, pressure and center of action

Due to the wind blowing over the water surface, waves are generated which exerts pressure on the reservoir. According to D. A. Molitor, the wave height h_w is given by
For Fetch F < 32 Km,
$h_w = 0.032\sqrt{VF} + 0.763 - 0.271\sqrt[4]{F}$ and
For F > 32 Km $h_w = 0.032\sqrt{VF}$
Where h_w is wave height in m, v = wind velocity in Kmph and F is fetch or straight length of water expanse in Km.
The intensity of pressure, $pw = 2.4\ \Upsilon_w h_w$ and total force $P_w = 2000\ h_w^2$ (Kg/m)
And acts at $\frac{3}{8}\ hw$ (= 0.375hw) above reservoir surface.

Silt pressure : the silt and debris deposited in the reservoir exerts silt pressure which can be determined as
$Ps = \frac{1}{2}\frac{1-\sin\emptyset}{1+sin\emptyset}\Upsilon^1 h^2$
Where $\emptyset$ = angle of internal friction of silt.
Υ^1 = submerged unit weight of silt.
h = depth of silt deposition.
If the upstream face is inclined then in addition to above horizontal force, the vertical force shall also be considered.

Wind pressure: it is a minor force and need hardly be considered. However, for the exposed area, the wind pressure is taken as 100 to 150 Kg/m^2.

LOAD COMBINATIONS FOR DESIGN

The design of a gravity dam is based on the most adverse combination of the loads (or forces) acting on it, which includes only those loads having a reasonable probability of simultaneous occurrence. The combinations of transient loads such as those due to maximum flood and earthquake are not considered because the probability of occurrence of each of these phenomena is quite a low and hence the probability of their simultaneous occurrence is almost negligible. Thus for the design of gravity dams IS; 6512-1984 specifies the load combination A,B,C,D,E,F,G as indicated below.

a) Load combination A (Construction condition or Empty reservoir condition) Dam completed but no water in reservoir and no tail water.
b) Load combination B (Normal Operating Condition) - Full reservoir elevation normal dry weather tail water, normal uplift; ice and silt (if applicable).
c) Load combination C (Flood Discharge Condition) - Reservoir at maximum flood pool elevation, all gates open, tail water at flood elevation, nor-ma1 uplift, and silt (if applicable).
d) Load combination D - Combination A, with earthquake.
e) Load combination E - Combination B, with earthquake but no ice.
f) Load combination F - Combination C, but with extreme uplift (drains in operative).
g) Load combination G - Combination E, but with extreme uplift (drains in operative).

Stability analysis – modes of failure

1. Factor of safety against overturning.
2. Factor of safety against sliding.
3. Compression and tension.

Overturning:

The overturning of dam takes place when the resultant force passes through the downstream toe. On the other hand, if the resultant cuts the base within the body of dam, no overturning occurs.

The factor of safety against overturning

$= \frac{\sum MR}{\sum MO} = \frac{\text{sum of resistiing moment at toe}}{\text{sum of overturing moment at toe}}$

Sliding:

If the horizontal sliding forces are greater than resisting forces above any level, the dam may fail due to sliding at that level. The resistance may be due to friction or due to friction and shear strength of joint. Shear strength is developed due to proper bond at joints and at bended foundations.

The factor of safety against sliding without shear strength

$= \frac{\mu \sum V}{\sum H}$

Where μ = coefficient of friction = 0.65 to 0.75.

$\sum V$ = net vertical force.

And $\sum H$ = net horizontal force.

Compression and tension –

The normal stress at any point on the base of the dam is obtained as,

$Pn = \frac{\sum V}{b}\left[1 \pm \frac{6e}{b}\right]$

Where b = width of dam section.

$\sum V$ = net vertical force and

E = eccentricity = $\frac{b}{2} - x$

$X = \frac{\sum M}{\sum V} = \frac{(\sum MR - \sum Mo)}{\sum V}$

Normal stress at toe, $(pn)_{toe} = \frac{\sum V}{b}\left[1 + \frac{6e}{b}\right]$

At heel, $(pn)_{heel} = \frac{\sum V}{b}\left[1 - \frac{6e}{b}\right]$

When the normal stress at toe, $(pn)_{toe} > f$, allowable compressive stress of dam material, the material starts crush. Hence, the effective width reduces.

On the other hand, when (pn) heel becomes tensile (-ve), tension cracks are developed, leading to failure of dam.

The stresses depend on material strength and quality.

Principle and shear stresses : An element considered at heel as shown in figure is subjected to water pressure which acts perpendicular to the face without any tangential stress and hence it is normal stress on normal plane AB called principle stress. As principal planes will be normal to each other, plane AC is also the principle plane and the stress ϵ1 acting on it is the principle stress.
Resolving the forces in vertical direction, if pe1 is intensity of hydrodynamic pressure then
At heel, $\sigma_1 = p_n \sec^2\varphi - (p + p_e) \tan^2\varphi$
At toe, $\sigma_1 = p_n \sec^2\varphi - (p - p_e) \tan^2\varphi$similarly, resolving the forces in horizontal direction, considering hydrodynamic pressure intensity,
At heel, ϵ = $[p_n - (p + p_e)] \tan\varphi$ At toe, ϵ = $[p_n - (p - p_e)] \tan\varphi$

Elementary profile of a gravity dam
When the gravity dam is subjected to water pressure alone, the elementary profile will be a triangle with zero width at top and maximum at base having the shape of hydrostatic water pressure diagram. When this dam section is under reservoir empty condition, the resultant force passes through upstream middle third point M1. However, under reservoir full condition the following forces are considered to arrive at elementary profile of the dam.

(i) Weight of the dam $W = \rho\, \Upsilon_w \frac{1}{2} BH$ 20

(ii) Water pressure $P = \frac{1}{2} \Upsilon_w H^2$ 21

(iii) Uplift pressure $U = \frac{1}{2} C\Upsilon_w HB$ 22

Where ρ = specific gravity of dam material,
C = uplift pressure intensity coefficient.

Practical profile of a Gravity Dam
The practical profile includes – the roadway at top, additional load due to road, free board. These provisions make the resultant force getting shifted towards the toe. To eliminate tension at heel, some masonry is added on upstream face. The top width for roadway = a = 14% of height of dam.Freeboard = 1.5 times height of wave above normal pool elevation or maximum reservoir level which ever gives highest crest elevation. The freeboard above maximum reservoir level shall not be less than 0.9 m. further, while determining height of wave, the wind velocity shall be taken as 120 Km/h over normal pool condition and 80Km/h over MWL.

Methods of design of gravity dams
The various methods used for the design of gravity dams are as follows.
[1] Stability analysis method
[2] Zone of determination of Profile of a dam.

Stability analysis method
In this method a trial section of the dam is first assumed on the basis of the previous designs, experience, configuration of valley, etc. The stability of the assumed section is then checked at the foundation level as well as at other levels. The various methods used for stability analysis are:
[1] Gravity method
[2] Trial load twist method
[3] Experimental method
[4] Slab analogy method
[5] Lattice analogy method
[6] Finite element method

Gravity method
In this method the dam is considered to be composed of a series of vertical cantilevers independent of each other and the load acting on the dam is transferred to the foundation through cantilever action. For the sake of convenience a cantilever of unit length contained between two vertical planes normal to the axis of the dam is considered above the deepest foundation level and its stability is checked against all the possible modes of failure. At the base of the dam as well as at various horizontal sections above the base. If necessary the assumed dam section is modified and when a section satisfying the stability requirements is obtained the same is adopted for the entire dam. The various steps involved in this method are as indicated below
a. Calculate all the forces acting per unit length of the dam considered above the deepest foundation level.
b. Find the horizontal and vertical components of all the forces.
c. Find Σ H the algebraic sum of all the horizontal forces and ΣV the algebraic sum of all the vertical forces.

d. Find the moments of all the forces about the toe of the dam and compute ΣM_O the sum of the overturning moments and the ΣM_R the sum of the righting moments. Also find the algebraic sum of all the moments
$\Sigma M = (\Sigma MR - \Sigma M_O)$
e. Find the distance $\bar{x}$ of the point of intersection of the resultant R with the base from the toe of the of the dam using the relation
$$\bar{x} = (\Sigma M / \Sigma V)$$
f. Find the eccentricity e, which is the distance between the centroid of the area of the base when the point of intersection of the resultant with the base, as given by the expression
$$e = (b/2) - \bar{x}$$
g. Find the normal stress at the toe as well as heel of the dam given by equation
$\sigma_y = (\Sigma V / b) * (1 \pm (6e/ b))$
h. Find the principle and shear stresses at the toe and the heel of the dam given by previous equations.
i. Find the factor of safety against overturning by the expression
$$F.S = (\Sigma M_R/\Sigma M_O)$$
j. Find the factors of safety against sliding given by previous equations.

Design of gravity dam – multiple step method

The dam section is divided into seven zones and each zone is designed to satisfy the stability requirements.

Zone I: It is the portion above maximum water level (or bottom of ice sheet, if exists). If there is no ice, the height of zone I is governed by free board.

Zone II: this is the portion for which both upstream and downstream of dam are kept vertical. The position of the bottom of the dam is obtained such that the resultant force with reservoir full passes through outer middle third point. However, when reservoir is empty, resultant lies within middle third portion.

Zone III: In this zone,upstream face remains vertical, while downstream face is inclined. When the reservoir is full, the resultant force continues to coincide with the outer middle third point. The height of the zone is determined when the resultant with reservoir empty passes through inner middle third point.

Zone IV: In this zone, both upstream and downstream faces are inclined, so that the resultant coincides both extreme middle third points under respective conditions. The height of the zone is governed by the criterion that the maximum inclined pressure at downstream face for reservoir full condition is just equal to allowable limit. The height and upstream and downstream slopes of this zone is determined by trial, dividing the zone into several blocks. Low dam lie within the limit of zone IV.The dam designed in this study is assumed with a top width of 7.5 m (two lane). After initial calculations the height for Zone 1 (free board) is fixed as 2.5 m. by trial and error the height for zone II is decided as 5.4 m with the base width of 7.5 m. with this Zone III is designed by making blocks of 3 mtr height and downstream slope is decided accordingly and zone III has 13.5 m height with the base width of 16.71 mtrs. Zone IV has got both the upstream and downstream slopes, here the blocks are of 5 mtr height. Finally height for zone IV is 13 mtrs. As the dam we designed is a low dam (<45 mtrs) so the height is 40.4mtrs with the base width of 38.65 mtrs. Tail water is provided at the height of 8 mtrs at the downstream side and drainage gallery is fixed at 6.5 mtrs from the heel for the practical profile of the gravity dam with the intensity of 0.1g. Thus the stability of the dam is safe for this conditions up to 0.15g with the upstream slope as 0.15:1 and downstream slope 0.88:1.

V. METHODOLOGY

- When a solid gravity dam is to be designed for an irrigation project, initially its elementary profile (triangular section) is decided.
- Then the elementary profile is modified to suit the practical conditions. These conditions are
  1) A suitable freeboard is provided to prevent overflow
  2) A suitable top width is provided for inspection and conveyance purpose.
- Due to such provisions the weight of the dam increases at the top portion, which creates instability of the section in reservoir empty condition and tension may be developed at the toe.
- Hence it becomes necessary to increase weight on the upstream side and hence a batter is provided on the upstream side.

- But for reservoir full condition, the resultant of all the forces remains in the middle third portion and the section becomes quite safe. Hence to provide economy, the material from the downstream side may be removed.
- The addition of the quantity of material on the upstream and deduction of quantity of material from the downstream are the function of top width of the section.
- The net cross-sectional area of the dam is determined at a particular value of top width.
- The section, for which the net cross-sectional area of the dam is minimum, is known as the optimal section. The top width is taken as the function of the height of the dam.
- The preparation of a simplified computerized method using MS-Excel is used to determine the optimal section of the dam. The computerized methodology provides computation of the optimal section for a wide range of height of a gravity dam.
- This methodology also provides computation of the optimal section for a wide range of top width of a gravity dam.
- This methodology helps us to choose the optimal section by calculating the areas of concrete of various sections *i.e.* the section with minimum area of concrete is the optimal section.

VI. OBJECTIVES:

[1] To carry out multiple step method of design.
[2] To decide optimum location of drainage gallery to reduce the uplift pressure.
[3] Back water calculations due to construction of the dam.
[4] To design concrete gravity dam for varying horizontal earth quake intensities from 0.1g to 0.3g with 0.05g increment to take into account the uncertainty and severity of earthquake intensities.

VII. CONCLUSION

This study assures the stability of the dam at each blocks. Afterall the calculations, we make sure that eccentricity e is less than or equal to b (base width)/6. The dam can resist the earthquake intensity up to 0.15g.

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