The aim of the study is to analyse the dam for stability and seismic forces. Dam being one of the mega structures it becomes prime important to design and analyse such structure with keen observation considering various factors affecting them. As it is one of the lifeline structures, it is again important to analyse such structure for major forces like earthquake. Keeping this in mind, in this paper the study is done for finding out the result that makes dam stable against forces acting on it with and without considering seismic forces. The study is done considering the hypothetically dam subjected to pre decided geographical factors like type of soil, its density, seismic zone etc. further this experimental work is done for dam full (with and without considering uplift pressure) and empty condition. This designing is done following IS code criteria. Further in paper work various such gravity dams subjected to different factors are analysed. The results of analysis are tabulated over here and the various forces responsible for failure of dam are highlighted in conclusion.

Keywords— Gravity Dam, Seismic Forces, Sliding, Stability, Analysis

I. INTRODUCTION

Gravity dams are solid concrete structures that maintain their stability against design loads from the geometric form, mass and potancy of the concrete. The purposes of dam creation may comprise routing, flood damage reduction, hydropower creation, fish and wildlife improvement, water superiority, water supply, and amusement. The plan and assessment of concrete gravity dam for earthquake loading must be based on suitable criterion that be a sign of both the preferred level of safety and the variety of the design and evaluation events.

Basically, a gravity concrete dam is defined as a formation, which is planned in such a manner that its own weight resists the outer forces. It is principally the weight of a gravity dam which prevents it from being upturned when subjected to thrust of impounded water. This type of formation is strong, and requires very little repairs. Gravity dams typically consist of a non-overflow section and an spill over section or spillway. The two common concrete construction methods for concrete gravity dams are conventional positioned mass concrete and RCC Gravity dams, built in stone masonry, were built even in earliest times, often in Greece, Egypt, and the Roman Empire. Nevertheless, concrete gravity dams are favored these days and frequently constructed. They can be constructed with ease on any dam site, where there exists a natural base strong enough to bear the massive load of the dam. Such a dam is in general straight in plan, even though sometimes, it may be a little curve. The line of the upstream face of the dam or the line of the coronet of the dam if the upstream face in slanting, is taken as the orientation line for layout purpose, etc. and is known as the “Base line of the Dam” or the “Alignment of the Dam”. When appropriate environment are on hand, such dams can be constructed up to huge heights. The ratio of base width to height of high gravity dams is generally less than 1:1

II. SCOPE

Over here the seismic and stability Analysis of RCC gravity dam is done which is trapezoidal in shape

III. DESIGN PHILOSOPHY

Such a dam is generally straight in plan, although sometimes, it may be to some extent curve. The line of the upstream side of the dam or the line of the coronet of the dam if the upstream side in slanting, is considered as the orientation line for plan purposes, etc. and is known as the “Base line of the Dam” or the “Axis of the Dam”. When appropriate circumstances are on hand, such dams can be constructed up to immense heights. The ratio of base width to height of high gravity dams is generally less than 1:1. A typical cross-section of a high concrete gravity dam is shown in figure alongside. The upstream face may be kept throughout perpendicular or partially slanting for some of its length. A drainage passage is usually provided in order to lessen the uplift pressure formed by the seeping water. Purposes valid to dam creation may include routing, flood damage reduction, hydropower creation, fish and wildlife improvement, water superiority, water supply, and amusement. Several concrete gravity dams have been in use for more than five decades, and over this phase significant advances in the methodologies for assessment of natural phenomena hazards have caused the design-basis events for these dams to be revised upwards. Older existing dams may fail to meet revised safety criteria and structural rehabilitation to meet such criteria may be costly and difficult. The identified causes of failure, based on a study of over 1600 dams are: Foundation problems (40%), Inadequate spillway (23%), Poor construction (12%), Uneven settlement (10%),
High poor pressure (5%), Acts of war (3%), Embankment slips (2%), Defective materials (2%), Incorrect operation (2%), and Earthquakes (1%). Other surveys of dam failure have been cited by [5], who estimated failure rates from $2 \times 10^{-4}$ to $7 \times 10^{-4}$ per dam-year based on these surveys.

IV. EXPERIMENTAL WORK

Check the stability of gravity dam section shown in fig. For reservoir empty and full condition considering seismic forces assume reasonable value of uplift and a line of drain holes 6m downstream of the upstream face for the purpose of this check assume water level at the top of dam and no tail water. Also find principal and shear stresses at the toe & heel of dam. Take unit weight of concrete 24 KN/M$^3$ shear strength of concrete as 2200 KN/M$^2$ and $\mu=0.7$.

![Diagram of dam section](image)

Solution:

Stability check of dam without considering seismic forces

CASE I:- Reservoir empty condition.

When reservoir is empty only self weight of dam will be acting as force. Other forces such as water pressure & uplift will be zero. The resulting force $\Sigma V_1$ and resulting moment $\Sigma M_1$ for this case has worked out as follows:
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Item description</th>
<th>forces</th>
<th>Lever arm</th>
<th>moment at toe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Vertical</td>
<td>Horizontal</td>
<td>+ve</td>
</tr>
<tr>
<td>1.</td>
<td>W₁ 90×71×24</td>
<td>15120</td>
<td>53.5</td>
<td>808</td>
</tr>
<tr>
<td>2.</td>
<td>W₂ ½ ×50×80×24</td>
<td>48000</td>
<td>33.3</td>
<td>159</td>
</tr>
<tr>
<td>3.</td>
<td>W₃ ½ ×3×90/2×24</td>
<td>1620</td>
<td>58</td>
<td>939</td>
</tr>
<tr>
<td></td>
<td>∑V₁ = 64200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>∑M₁ = 2502720</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WATER PRESSURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>P₄ 3×45× ½×9.81</td>
<td>662.175</td>
<td>59</td>
<td>390</td>
</tr>
<tr>
<td>5.</td>
<td>P₅ 3×45×9.81</td>
<td>1324.35</td>
<td>58.5</td>
<td>774</td>
</tr>
<tr>
<td></td>
<td>H ½×90²×9.81</td>
<td>39730.5</td>
<td>90/3</td>
<td>1191915</td>
</tr>
<tr>
<td></td>
<td>∑M₂ = 1427347.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UPLIFT FORCES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>U₆ 882.9/3×54× ½</td>
<td>-7946.1</td>
<td>36</td>
<td>286059.6</td>
</tr>
<tr>
<td>7.</td>
<td>U₇ 882.9/3×6×1</td>
<td>-1765.8</td>
<td>57</td>
<td>100650.6</td>
</tr>
<tr>
<td>8.</td>
<td>U₈ 2×882.9/3×6×1×1/2×1</td>
<td>-1765.8</td>
<td>58</td>
<td>102416.4</td>
</tr>
<tr>
<td></td>
<td>∑V₃ =54 708.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>∑M₃ =938221.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Position of resultant from toe

\[ X = \frac{\sum M_1}{\sum V_1} = \frac{2502720}{64200} = 38.98 \text{m} \]

Its distance from centre is

\[ e = \frac{b}{2} - X = \frac{60}{2} - 38.98 = -8.98 \text{m} \]

(i.e. the resultant falls to the left of the center)

Normal compressive stress at toe

\[ P_n = \frac{\sum V_1}{b (1+6e/b)} = \frac{64200/60 (1+6(-8.98)/60)}{109.14 \text{ KN/m}^2} (0.109\text{N/mm}^2) \]

Normal compressive stress at heel

\[ P_n = \frac{\sum V_1}{b (1-6e/b)} = \frac{64200/60 (1-6(-8.98)/60)}{2030.86 \text{ KN/m}^2} (2.030 \text{ N/mm}^2) \]

Principal stress at toe

\[ \sigma_1 = P_n \sec^2 \Phi \quad \text{where} \quad \tan \Phi = 0.625 \]

\[ = 109.14 \times 1.39 \quad \sec^2 \Phi = 1.39 \]
\[
\text{Principal stress at heel} \\
\sigma = P_n \sec^2 \theta \\
\text{where } \tan \theta = 3/45 = 0.07 \\
= 2030.86 \times 1 \\
\sec^2 \theta = 1 \\
= 2030.86 \text{ KN/m}^2 (2.030 \text{ N/mm}^2)
\]

Shear stress at toe
\[
\tau = P_n \tan \Phi \\
= 109.14 \times 0.625 \\
= 68.21 \text{ KN/m}^2 (0.068 \text{ N/mm}^2)
\]

Shear stress at heel
\[
\tau = P_n \tan \theta \\
= 2030.86 \times 0.07 \\
= 142.16 \text{ KN/m}^2 (0.142 \text{ N/mm}^2)
\]

CASE II: Reservoir full with no uplift

Calculation of stresses
\[
\tan \Phi = 0.625, \sec^2 \Phi = 1.39 \\
\tan \theta = 0.07, \sec^2 \theta = 1
\]

Position of resultant from toe
\[
X = \frac{\sum M_2}{\sum V_2} = \frac{1427347.8}{66186.52} = 21.56 \text{m}
\]

Position of resultant from the centre of the base is
\[
e = \frac{b^2}{2} - X = 30 - 21.56 = 8.44 \text{m}
\]

Normal compressive stress at toe
\[
P_n = \frac{\sum V_2}{b (1+6e/b)} \\
= 66186.52/60 (1 + 6 \times 8.44/60) \\
= 2034.13 \text{ KN/m}^2 (2.034 \text{ N/mm}^2)
\]

Normal compressive stress at heel
\[
P_n = \frac{\sum V_2}{b (1-6e/b)} \\
= 66186.52/60 (1 - 6 \times 8.44/60) \\
= 172.08 \text{ KN/m}^2 (0.172 \text{ N/mm}^2)
\]

Principal stress at toe
\[
\sigma_1 = P_n \sec^2 \Phi \\
= 2034.13 \times 1.39 \\
= 2827.44 \text{ KN/m}^2 (2.827 \text{ N/mm}^2)
\]

Principal stress at heel
\[
\sigma = P_n \sec^2 \theta - P \tan^2 \Phi \\
= 172.08 \times 1 - (9.81 \times 90) \times 4.9 \times 10^{-3} \\
= 167.75 \text{ KN/m}^2 (0.167 \text{ N/mm}^2)
\]

Note: This is the value for minor principal stress at the heel. The value of major principal stress at heel = 9.81 x 90 = 882.9 KN/m²

Shear stress at toe
\[
\tau = P_n \tan \Phi = 2034.13 \times 0.625 = 1271.33 \text{ KN/m}^2
\]

Shear stress at heel
\[
\tau = -(P_n - P) \tan \theta = -(172.08-882.9) \times 0.07 \\
= 49.75 \text{ KN/m}^2
\]

The factor of safety against sliding and overturning should be found out only when reservoir is full & Full uplift acts, since the condition of sliding & overturning will be more critical in that case.
CASE III: - Reservoir full with uplift

Position of resultant from toe
\[ X = \frac{\sum M_3}{\sum V_3} = \frac{938221.2}{54708.82} = 17.14 \text{m} \]
Position of resultant from the centre of the base is
\[ e = \frac{b}{2} - X = 30 - 17.14 = 12.86 \text{m} \]

Normal compressive stress at toe
\[ P_n = \frac{\sum V_3}{b} \left(1 + \frac{6e}{b}\right) \]
\[ = \frac{54708.82}{60} \left(1 + \frac{6 \times 12.86}{60}\right) \]
\[ = 2084.40 \text{ KN/m}^2 \left(2.084 \text{ N/mm}^2\right) \]
This compressive stress is greater than that obtained for case II, hence this is worst case.

Normal compressive stress at heel
\[ P_n = \frac{\sum V_3}{b} \left(1 - \frac{6e}{b}\right) \]
\[ = -260.77 \text{ KN/m}^2 \left(-0.260 \text{ N/mm}^2\right) \]

Principal stress at toe
\[ \sigma_1 = P_n \sec^2 \Phi \]
\[ = 2084.40 \times 1.39 \]
\[ = 2897.31 \text{ KN/m}^2 \left(2.897 \text{ N/mm}^2\right) \]

Principal stress at heel
\[ \sigma = P_n \sec^2 \theta - P \tan^2 \Phi \]
\[ = 260.77 \times 1 - (9.81 \times 30) \times 4.9 \times 10^{-3} \]
\[ = 256.44 \text{ KN/m}^2 \left(0.256 \text{ N/mm}^2\right) \]

Shear stress at toe
\[ \tau = P_n \tan \Phi = 2084.4 \times 0.625 = 1302.75 \text{ KN/m}^2 \]

Shear stress at heel
\[ \tau = -(P_n - P) \tan \theta = -(260.77 - 882.9) \times 0.07 \]
\[ = 43.54 \text{ KN/m}^2 \]

Calculation of factor of safety

Factor of safety against overturning
\[ = \frac{\sum M(+) + \sum M(-)}{\sum M(-)} = \frac{2619262.8}{1681041.6} = 1.55 > 1.5 \text{ Hence safe} \]

Factor of safety against sliding
\[ = \left(\mu \frac{\sum V_3}{\Sigma H}\right) = \left(0.7 \times 54708.82\right)/39730.5 \]
\[ = 2.33 > 2 \text{ Hence safe} \]

Shear friction factor
\[ S.F.F. = \left(\mu \frac{\sum V_3 + b \times c'}{\Sigma H}\right) \]
\[ = \left(0.7 \times 54708.82 + 60 \times 2200\right)/39730.5 \]
\[ = 4.28 > 4 \text{ Hence safe} \]

Safety against sliding as per IS 6512-1984
Taking \( f_0 = 1.5 \) & \( f_c = 3.6 \) for loading combination B,
\[ F = \left[\left(\mu \frac{\sum V_3}{\mu_0}\right) + c (b' / L_2)\right]/\Sigma H \]
\[ = \left[\left((0.7 \times 54708.82)/1.5\right) + (2200\times60)/3.6\right]/39730.5 \]
\[ = 1.56 > 1. \]
Hence safe

Stability check of dam by considering seismic forces:
For worst condition consider that,

a) Horizontal earthquake acceleration acts upstream.

b) Vertical earthquake acceleration acts downwards.

Hydrodynamic pressure due to water caused by earthquake can be found out from zangers formula. Since the slope is up to middle depth, approximate value of θ can be found out by joining heel to the upstream edge.

\[
\tan \theta_1 = \frac{3}{90} = 0.033 \quad \text{or} \quad \theta_1 = 1.89^\circ
\]

\[C_m = 0.735 \times (1 - (1.89^\circ/90^\circ)) = 0.72\]

At base \(C = C_m\)

Therefore \(p_e = C_m \alpha h\)

By clause 3.4.2.3 of IS 1893-1984

\[\alpha_h = \beta I \alpha_0\]

\[\beta = 1 \quad \text{(By table 3)}\]

\[I = 3 \quad \text{(By table 4)}\]

\[\alpha_0 = 0.02 \quad \text{(considering zone II in table 2)}\]

\[\alpha_h = 1 \times 3 \times 0.02 = 0.06\]

Now by clause 7.3.1 for dams up to 100m height the value of \(\alpha_h = 1.5 \times \alpha_h\)

\[\alpha_h = 1.5 \times 0.06 = 0.09\]

and \(\alpha_v = 0.75 \times \alpha_h\)

\[\alpha_v = 0.75 \times 0.06 = 0.045\]

\[p_e = C_m \alpha_h \alpha_v w h\]

\[= 0.719 \times 0.09 \times 9.81 \times 90\]

\[= 57.13 \text{ KN/m}^2\]

Total pressure \(P_e = 0.726 p_e\)

\[= 0.726 \times 57.13 \times 90\]

\[= 3732.87 \text{ KN}\]

Moment due to this force at base,

\[M_e = 0.299 p_e h^2\]

\[= 0.299 \times 57.13 \times 90^2\]

\[= 138363.14 \text{ KN-m}\]

Calculation of forces and moments due to inertial earthquake force is done below:

Additional forces and their moments due to earthquake

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Item</th>
<th>Description</th>
<th>Forces(KN)</th>
<th>Lever arm(m)</th>
<th>Moment of toe(KN-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>Horizontal</td>
<td>+ VE</td>
<td>- VE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Inertial force due to earthquake on weight of dam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>(\Sigma V1)</td>
<td>(\Sigma V1 \times \alpha_v)</td>
<td>-2889</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Position of resultant from toe
X = \sum M_i/ \sum V_i = 509546.23/57597.82 = 8.84m
Hence the resultant does not lie within the middle third.

Position of resultant from the centre of the base is
e = b/2 - X = 30 - 8.84 = 21.16m
(i.e. the resultant falls to the right of the center)

Normal compressive stress at toe
\[ P_n = \sum V_i b (1+6e/b) = 57597.82/60(1 + 6 \times 21.16/60) \]
= 2991.24 KN/m² (2.991 N/mm²)

Normal compressive stress at heel
\[ P_n = \sum V_i b (1-6e/b) = 57597.82/60 (1 - 6 \times 21.16/60) \]
= -1071.31 KN/m² (-1.071 N/mm²)

Since the resultant does not fall within middle third and the value of tensile stress is
Substantial (>0.2f_c for M15 concrete) the dam is unsafe under seismic condition.

Principal stress at toe
\[ \sigma_1 = P_n \sec^2 \Phi \]
\[ = 2991.24 \times 1.39 \]
= 4157.82 KN/m² (4.157 N/mm²)

Principal stress at heel
\[ \sigma = P_n \sec^2 \theta - (P + P_e) \tan^2 \theta \]
\[ = -1071.31 \times 1 -((9.81x90)+57.13) \times 4.9 \times 10^3 \]
= -1075.91 KN/m² (-1.075 N/mm²)

Hence unsafe

Shear stress at toe
\[ \tau = P_n \tan \Phi = 2991.24 \times 0.625 = 1869.525 \text{ KN/m}^2 \]
Shear stress at heel
\[ \tau = -(P_n - (P + P_e))\tan\theta \]

Calculation of factor of safety

Factor of safety against overturning

\[ = \frac{\sum M(\text{+})}{\sum M(\text{-})} = \frac{2619262.8}{2109716.57} \]

\[ = 1.24 < 1.5 \text{ Hence unsafe} \]

Factor of safety against sliding

\[ = \left( \frac{\mu}{\sum H} \right)^4 = \frac{(0.7 \times 57597.82)}{48289.97} \]

\[ = 0.83 < 1.5 \text{ Hence unsafe} \]

Shear friction factor

\[ \text{S.F.F.} = \frac{\mu (\sum V^4 + b \times c)}{\sum H} \]

\[ = \frac{(0.7 \times 57597.82 + 60 \times 2200)}{48289.97} \]

\[ = 3.56 > 3 \]

Safety against sliding as per IS 6512-1984

Taking \( f_0 = 1.2 \) & \( f_c = 2.7 \) for loading combination E,

\[ F = \frac{[(\mu \sum V) / f_0] + (c b / f_c)]}{\sum H} \]

\[ = \frac{[(0.7 \times 57597.82) / 1.2 + ((2200 \times 60) / 2.7)]}{48289.97} \]

\[ = 1.7 > 1 \text{ Hence safe} \]

V. RESULT AND OBSERVATION

Comparative results are tabulated for problem analysed with and without seismic forces manually

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Action/ consideration</th>
<th>Magnitude</th>
<th>Effect</th>
<th>Check</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In absence of Seismic forces</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>F.O.S.against overturning</td>
<td>1.55</td>
<td>Overturning</td>
<td>safe</td>
<td>stable</td>
</tr>
<tr>
<td>2</td>
<td>F.O.S.against sliding</td>
<td>2.33</td>
<td>Sliding</td>
<td>safe</td>
<td>stable</td>
</tr>
<tr>
<td>3</td>
<td>Shear friction factor</td>
<td>4.28</td>
<td>Shearing</td>
<td>safe</td>
<td>stable</td>
</tr>
<tr>
<td>4</td>
<td>Safety against sliding As per IS 6512-1984</td>
<td>1.56</td>
<td>Sliding</td>
<td>safe</td>
<td>stable</td>
</tr>
<tr>
<td></td>
<td>Seismic forces effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>F.O.S.against overturning</td>
<td>1.24</td>
<td>Overturning</td>
<td>unsafe</td>
<td>unstable</td>
</tr>
<tr>
<td>2</td>
<td>F.O.S.against sliding</td>
<td>0.83</td>
<td>Sliding</td>
<td>unsafe</td>
<td>unstable</td>
</tr>
<tr>
<td>3</td>
<td>Shear friction factor</td>
<td>3.56</td>
<td>Shearing</td>
<td>safe</td>
<td>stable</td>
</tr>
<tr>
<td>4</td>
<td>Safety against sliding As per IS 6512-1984</td>
<td>1.75</td>
<td>Sliding</td>
<td>safe</td>
<td>stable</td>
</tr>
</tbody>
</table>
Comment on stability & instability parameter on the basis of results obtained using staad pro software for different Zones

<table>
<thead>
<tr>
<th>FACTOR OF SAFTEY</th>
<th>ZONE II</th>
<th>ZONE III</th>
<th>ZONE IV</th>
<th>ZONE V</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACTOR OF SAFTEY AGAINST OVERTURNING</td>
<td>Unsafe</td>
<td>Unsafe</td>
<td>Unsafe</td>
<td>Unsafe</td>
</tr>
<tr>
<td>FACTOR OF SAFTEY AGAINST SLIDING</td>
<td>Unsafe</td>
<td>Unsafe</td>
<td>Unsafe</td>
<td>Unsafe</td>
</tr>
<tr>
<td>SHEAR FRICTION FACTOR</td>
<td>Safe</td>
<td>Safe</td>
<td>Safe</td>
<td>Safe</td>
</tr>
<tr>
<td>FACTOR OF SAFTEY AGAINST SLIDING AS PER IS 6512-1984</td>
<td>Safe</td>
<td>Safe</td>
<td>Safe</td>
<td>Safe</td>
</tr>
</tbody>
</table>

All the results are obtained using following basic load cases and their combinations with the help of staad pro software.

Total no of Nodes = 30
Total no of Plates = 70
Plate thickness = 15cm
All the bottom nodes are considered as fixed.

Materials

<table>
<thead>
<tr>
<th>Mat</th>
<th>Name</th>
<th>E (kN/mm²)</th>
<th>n</th>
<th>Density (kg/m³)</th>
<th>a (1/°K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>STEEL</td>
<td>205.000</td>
<td>0.300</td>
<td>7.83E 3</td>
<td>12E-6</td>
</tr>
<tr>
<td>4</td>
<td>ALUMINUM</td>
<td>68.948</td>
<td>0.330</td>
<td>2.71E 3</td>
<td>23E-6</td>
</tr>
<tr>
<td>5</td>
<td>CONCRETE</td>
<td>21.718</td>
<td>0.170</td>
<td>2.4E 3</td>
<td>10E-6</td>
</tr>
</tbody>
</table>

Basic Load Cases

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EQX</td>
</tr>
<tr>
<td>2</td>
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<td>WATER PRESSURE</td>
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<td>UPLIFT PRESSURE</td>
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Combination Load Cases

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VI. CONCLUSION

The behavior of Gravity dam for stability and response towards seismic forces are studied in this paper. With problem consideration the stability analysis of gravity dam is done in absence of seismic forces initially. Thus analysis highlighted that in presence of various loads like dead load, water/ hydrostatic pressure, uplift pressure, total cumulative values of +ve moment and -ve moment, summation of horizontal and vertical forces are overall responsible for dam stability.

Further with analysis it is clear that moment resulting due to self weight act as resistive moment against moment produced due to water, uplift pressure etc. Which means that stability against overturning is achieved when +ve moment is greater than -ve moments. Whereas stability against sliding depends upon coefficient of friction, sum of all vertical forces and all horizontal forces. Thus sliding is governed by uplift pressure. More friction coefficient & more summation of vertical forces results stability against sliding. However, if horizontal force increases stability against sliding decreases if vertical forces remain approximately same.

Third stability of dam is on basis of shear friction factor, this depends upon coefficient of friction, summation of all vertical forces, summation of all horizontal forces, geometry of dam and materials shear strength. For same problem material shear strength, geometry friction remains unchanged, thus stability should depend upon sum of all vertical forces and all horizontal forces. For problem considered in study, dam achieves stability against all factors i.e. overturning, sliding & shearing.

Further same dam is analysed considering seismic forces. With introduction of seismic forces, there is change in behavior of dam against stability. From study it is very clear that for considered problem the value of +ve moment remained unchanged. Whereas resistivity i.e. -ve moment increased thus, dam is unstable against overturning for seismic force consideration. Again value of summation of vertical forces and summation of horizontal forces increased. This resulted instability against sliding, however stable against shear force (as material, geometry & shear strength is constant in both cases). Thus, it can be concluded that for gravity dam considered over here in study reflects that the dam was stable against overturning, sliding and shearing in absence of seismic forces. But, with introduction of seismic forces dam turned unstable against overturning and sliding.

The study is further carried out to observe the change in analysis values of moments, vertical and horizontal actions with change in seismic zones. For same loading and geometry consideration, when analysis is done for various seismic zone, it is observed that values of +ve moment remains constant where as the value of –ve moment increased with increase in earthquake severity zone wise. This highlights instability against overturning. Again, it is observed that value of vertical forces remained unchanged but seismic forces increases value of horizontal forces which resulted in instability against sliding.
REFERENCES


