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Effect of the Symmetrical Variation of Top Width on the Stability of Concrete Gravity Dam, using the Classical Theory.

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Abstract-* *The history of dam dates back to ancient civilization, and to this very day it still plays a huge role in the in everyday life of man. From power generation, to irrigation, and from tourism to fish farming the role of dam to the socio-economic wellbeing of any nation cannot be overstated. Due to its importance and the huge resources involved in dam construction, scientist over the years have sort to understand the engineering dynamics of dam structures to ensure their durability and stability, thereby developing various theories for the analysis of dam. Due to its simplicity and yet completeness in addressing the different aspect of dam stability, this study used the classical theory of beams to study the effect of top width variation on the stability of concrete gravity dams. The study section has a bottom width of 10m, a top width varying from 0 to 10m given us 11 study cases. The study reveals that the ratio of the top width of the dam to the bottom width plays a big role in the stability of the dam. We found the optimum top width to bottom width ratio to be 0.6, for a symmetrical trapezoidal gravity dam. The study further reveals that the rectangular dam is the most stable of the three dam sections identified by our study variations, followed by trapezoidal dams, and finally by triangular dams. The study further buttressing the findings in literatures that gravity dam offer good resistance to the forces acting on the dam.

Index Terms* - *Gravity, Dam, Symmetrical, Stability, Classical Theory, Width variation.

I. INTRODUCTION

A Dam can be defined as a hydraulic structure or a barrier built across a river, a stream, or an estuary to retain water on its upstream face. Dams are built to provide water for human consumption, for power generation, for use in industrial processes, for fishing, recreational purposes, and for irrigating arid and semiarid lands. A Dam may perform only one of the above functions and are thus referred to as single purpose dam, or two or more of the above purposes and are thus referred to as multi-purpose dam. The upstream part of the dam is where the water is flowing from, whereas the downstream is where the water is flowing to. In a multipurpose scheme, dam is usually the central structure designed to conserve water resources on a regional basis. Such a scheme is vital to the development of any nation, as dam may play different roles ranging from water supply, Industrial growth, hydroelectric power generation, to agricultural development through irrigation.

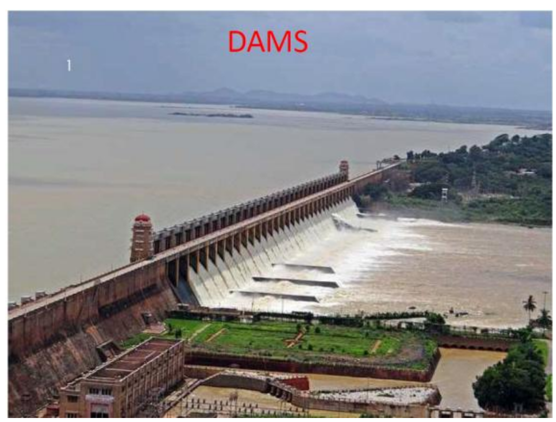

Fig 1.1: A Gravity Dam

1.1: Effects of Dam Development.

Despite the huge economic values accruing from the development of Dam, it has a lot of social and environmental challenges. These include:

- Displacement of large home land and communities.

- Distortion of natural balance of the aquatic life, leading to migration of fishes.
- Dam project if not properly planned and managed can lead to flooding in some areas.
- It can breed mosquitoes in the adjacent communities,
- It can also lead to the salinization of adjacent farm lands due to uncontrolled infiltration of water from unlined canals, etc.

1.2: Development of modern structural theory of Dams.

The conventional structural theory governs the design of concrete and masonry dams. This theory centers on the geometry of gravity dams in which the hydrostatic pressure of water retained in the dam is resisted by the weight of the dam itself and the inclined reaction of the dam's foundation. A more modern theory sees dam as a monolithic three-dimensional structure in which the distribution of stress and deflections of individual points depend on stresses and deflections of many other points in the structure. The later theory enables engineers to apply the finite element method, in the analysis of complex dam structures, leading to the development of highly sophisticated and highly efficient dams across the globe, such as the million dollars multi-purpose Shiroro and Kainji Dams in North-Central Nigeria.

1.3: Parts of Dam:

Different parts & terminologies of Dams:

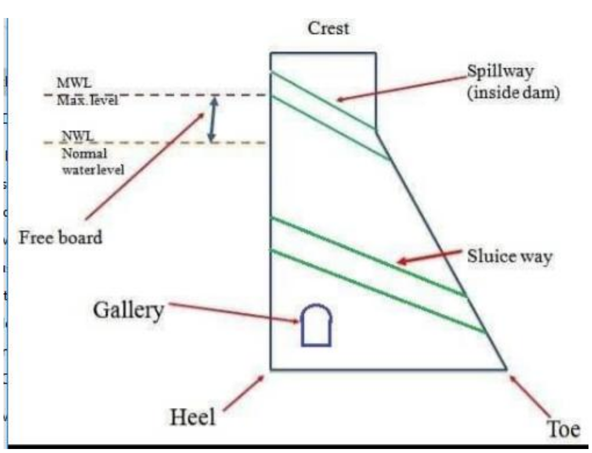

Fig 1.2: Parts of a Gravity Dam

- Crest: The crest is the top of the dam structure. It is often used for providing walkway or roadway over the dam.
- Parapet walls: Is a Low protective wall(s) on either side of the walkway or roadway on the crest.
- Heel: Is a Part of dam structure in contact with ground or river-bed at upstream side.
- Toe: Is a Part of dam structure in contact with ground or river-bed at downstream side.
- Spillway: Is a channel created near the top of the dam for the passage of excess water from the reservoir.
- Abutments: A part of structure sloping on either side of the dam wall and to which the left and right ends of dam are fixed to.
- Gallery: Level or gently sloping tunnel like passage (small room like space) at transverse or longitudinal within the dam with drain on floor for seepage water. These are generally provided for having space for drilling grout holes and drainage holes. These may also be used to accommodate the instrumentation for studying the performance of dam.
- Sluice way: Opening in the structure near the base, provided to clear the silt accumulation in the reservoir.
- Free board: This is the gap/space between the highest level of water in the reservoir and the top of the dam structure.
- Dead Storage level: Level of permanent in storage below which the water will not be withdrawn.
- Diversion Tunnel: Tunnel build to change the water course/direction in order to bypass the dam construction site, while the dam is being built. Water flows through the diversion tunnel while the dam is built.

II. LITERATURE REVIEW

2.1: Introduction

It is a common practice in engineering to apply numerical simulation in assessing the response of engineering projects. This application is seen all over civil engineering projects, from stability of structures, to dynamic analysis of Structures, and more recently to response of structures to seismic forces. Jiahao et al (2023), carried out Stability Analysis of Earth and Rock Dams During the Construction Period of Soft Foundation Reinforcement, using numerical simulation to study the strength law of soil and rock dam foundation under different consolidation coefficients. Their results showed that the larger the consolidation coefficient of soft ground, the more it is conducive to the growth of the strength of the soft soil layer and the greater is the stability coefficient of the earth and rock dam.

According to the International Committee of Large Dams (ICOLD 2024), Concrete gravity dams make up 14 % of the world's large dams. The increase in the number of gravity dams is due to the growing popularity of roller compacted concrete dams under suitable site conditions such as; favourable topography, material availability and good foundation. Concrete gravity dams are durable and have low maintenance cost compared to other dam types.

Sen L, et al.,(2021) used ANSYS to carry out a study on the influence of foundation parameters on the safety of dams .

Kun Y (2021), undertook infiltration as well as stability analysis of overflow dam section of a reservoir slurry masonry gravity dam based on numerical simulation for various working conditions in the field.

Zhang S, and Hu M(2020) studied the effect of flooding process on the stability of buildings using the embankment of Koster Power Station a case study.

Zhang L (2017) evaluated the permeability, stability and safety of earth -rock dam using numerical simulation, a case study of Chaohe Main Dam of Miyun Reservoir.

Cheng P (2020) undertook a stability and reliability study of earth–rock dam using limit equilibrium theory and numerical modelling, taking a case study of Three Gorges Reservoir.

Cassells and Blaeser (2024) carried out a review of stability acceptance criteria of concrete gravity dams. Their work provided a summary of the commonly adopted international dam design criteria from various Bodies with a focus on the differences between the prescribed considerations and criteria

2.2: Stability of Dams:

Rankine's work on the stability of loose earth, for example, provided a better understanding of the principles of dam design and performance of structures.

The structural stability of major dams needs to be re-evaluated every 5-10 years according to Hazard Classification Systems(HCS), most often within the legal framework of a governmental regulatory agency. Structural stability against sliding should satisfy a binary safe/unsafe limit-state stating that the shear resistance, R, has to be strictly larger than or equal to the driving shear load, L. To guard against uncertainties in R and L, large deterministic factors of safety (FSdet) are used. These large FSdet may be reduced when new knowledge about the material shear Strength parameter is acquired to better quantify the friction coefficient and cohesion. For instance, in CDA (2007), FSdet = 3 if no material test is available, and FSdet = 2 if tests are done(Mathilde Cordier and Pierre Léger, 2018)

2.2.1: Stability against Tension:

Stability against tension in the masonry of the dam is assessed majorly in terms of the position of the resultant force along the base of the dam. In order to maintain stability against tension in the dam masonry, the resultant force acting on the dam must lie within the middle third of the base width(ie within b/3 to 2b/3).

2.2.2: Overturning Stability

The overturning failure of a concrete gravity dam occurs when the total overturning moment about the downstream toe of the dam, exceeds the total restoring (resisting) moment. The moments are obtained by finding the moments of the various vertical and horizontal forces of each loading condition, about the toe of the dam. Dam design guidelines prepared by various engineering bodies across the world propose different methods for assessing the overturning stability of a concrete gravity dam. Overturning stability may be assessed in terms of the location of the resultant force acting along the base of the dam. The resultant must be located within the bounds of a defined ratio of the length of the central portion of the dam base. Or simply put, the line of action of the resultant force must pass through the base of the dam. Overturning stability of the dam may also be assessed by deriving an overturning FoS (factor of safety) as a ratio of the righting moment over the overturning moment (Durieux, 2008). Recommended overturning FoS criteria indicates that 1.5 is suitable for usual load combinations, 1.3 suitable for unusual load combinations and 1.1 for extreme load combinations (Watermeyer, 2006).

2.2.3: Stability against Sliding

The sliding failure of a concrete gravity dam may occur due to development of a sliding mechanism at the interface between the dam and foundation, or at any other interface within the dam body, or at geological interfaces within the underlying foundation Strata.

The sliding stability of a concrete gravity dam may be assessed by evaluating the sliding FoS, as a ratio of the stabilizing friction force (capacity) over the de-stabilizing shear force (demand) and comparing this to acceptance criteria. The shear force capacity is defined in terms of the Mohr-Coulomb Shear strength criterion of the failure interface.

2.3.4: Crushing/Material Strength Stability:

The crushing failure of the masonry of the base of the dam is deemed to have occurred when the maximum stress at the masonry base of the dam exceeds the permissible stress in the masonry. A material failure occur when development of internal stresses in the dam exceed the allowable factored material strength criteria, in relation to the respective loading condition.

3.2). : Stability Analysis of the Dam from the Classical Theory.

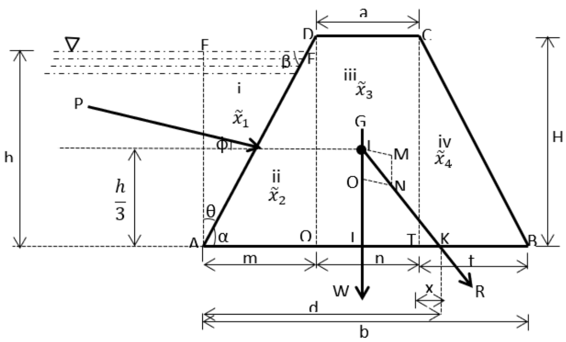

Fig. 3.1: A Cross Section of a Trapezoidal Gravity Dam with a Symmetrical Width Variation.

Fig 3.1 shows the cross-section of a trapezoidal gravity dam with symmetrically varying top width, from which we shall apply the classical theory of beams to derive expressions for assessing the stability of the dam.

3.1: Derivation of the Expression for the Forces Acting on the Dam.

From ΔAEF in Fig 3.1.

$$\cos\theta = \frac{AF}{AE} = \frac{h}{l} \tag{3.1}$$

$$\therefore l = \frac{h}{\cos\theta} \tag{3.2}$$

Total water pressure on a unit length of dam, P,

$$P = \frac{\omega h l}{2} \tag{3.3}$$

The water pressure has two components, horizontal and vertical components as stated below;

Horizntal coomponent of the water pressure Acting at a distance h/3 b/pressure, P_H, acting at $\frac{h}{3}$ from the base of the dam;

$$P_H = P\cos\emptyset \tag{3.4}$$

Substituting equations 3.2 and 3.3 into 3.4 we have

$$P_H = \frac{\omega h l}{2} \text{x} \frac{h}{l} = \frac{\omega h^2}{2}$$

$$P_H = \frac{\omega h^2}{2}$$

(3.5)

Equation (3.5) is the required expression for the Horizntal component of the water pressure.

Vertical coomponent of the water pressure pressure pressure, P_V;

$$P_V = P \sin \emptyset = \frac{\omega hl}{2} \text{x} \frac{FE}{l}$$

$$P_V = \frac{\omega}{2} \text{ x } |\text{FE}| \text{ x } h$$

(3.6)

Equation (3.6) gives expression for the weight of the wedge of water, a theoretical weight of water acting at the upstream face of the dam.

Thus, the total weight o the dam, W, is given by;

$$W = \text{weight of the wedge, AFE, +weight o the masonry ABCD}$$

$$\left(W = \frac{\omega}{2} \text{ x } |FE| \text{ x } h\right) + \left(\rho \text{ x} \frac{a+b}{2} \text{ x } H\right)$$

(3.7)

From , $\tan \alpha = \frac{|DQ|}{|AQ|}$, and from ΔAEF, $\tan \beta = \frac{|AF|}{|FE|}$

(3.8)

But $\alpha = \beta$ (Alternate angles)

$$\therefore \tan \alpha = \tan \beta$$

(3.9)

Substituting values in equation 3.8 into 3.9, we have,

$$\frac{|DQ|}{|AQ|} = \frac{|AF|}{|FE|} \gg |FE| = |AF| \text{ x } \frac{|AQ|}{|DQ|}$$

$$\therefore |FE| = |AF| \text{ x } \frac{|AQ|}{|DQ|}$$

$$|FE| = h \text{ x } \frac{|AQ|}{H}$$

$$|FE| = \frac{h}{H} \text{x} |AQ|$$

(3.10)

Where $|FE|$ is the width of wedge

Substituting 3.10 into 3.7, we have

$$\left(W = \frac{\omega h}{2} \text{ x } \frac{h}{H} \text{x} |AQ|\right) + \left(\rho \text{ x} \frac{a+b}{2} \text{ x } H\right)$$

$$\therefore \left(W = \frac{\omega h^2}{2H} \ |AQ|\right) + \left(\rho \text{ x} \frac{a+b}{2} \text{ x } H\right)$$

(3.11)

Equation 3.11 gives expression for the total weight of dam, W.

To obtain $|AJ|$, we take moment of all the forces about A, and equate same,

$$W \text{x} |AJ| = w_i \tilde{x}_1 + w_{ii} \tilde{x}_2 + w_{iii} \tilde{x}_3 + w_{iv} \tilde{x}_4$$

(3.12)

$$W \text{x} |AJ| = \left(\frac{\omega h^2}{2H} \ |AQ| \tilde{x}_1\right) + \left(\frac{1}{2}\rho . |QD| \, . |AQ| . \tilde{x}_2\right) + (\rho . |QT| \, . |QD| . \tilde{x}_3) + \left(\frac{1}{2}\rho . |TC| \, . |TB| . \tilde{x}_4\right)$$

(3.12)

Where,

$w_i =$ Weight of that section of the dam masonry, and,

$\tilde{x}_1 =$ The moment arm of that section of the dam masonry from point A.

$$\tilde{x}_1 = \frac{1}{3} FE \ = \frac{1}{3}\left(\frac{h.m}{H}\right)$$

$$\tilde{x}_2 = \frac{2}{3} AQ \ = \frac{1}{3}\left(\frac{h.m}{H}\right)$$

$$\tilde{x}_3 = \left(\frac{QT}{2} + AQ\right) \ = \frac{n}{2} + m$$

$$\tilde{x}_4 = \left(\frac{TB}{3} + AT\ \right) = \left[\frac{t}{3} + (m+n)\right]$$

(3.13)

$$W = \frac{wh^2}{2H} |AQ| \ + \ \frac{\rho H(a+b)}{2}$$

$$W = \frac{wh^2}{2H} m \ + \ \frac{\rho H(a+b)}{2}$$

(3.14)

Simplifying equation (3.12) more, we have,

Wx

$$|AJ| = \frac{wh^2}{2H}|AQ|\tilde{x}_1 + \frac{\rho}{2}|AQ||QD|\tilde{x}_2 + \rho|QT||QD|\tilde{x}_3 + \frac{\rho}{2}|TB||\widetilde{TC}|x_4$$

Wx

$$|AJ| = \frac{wh^2}{2H}m\tilde{x}_1 + \frac{\rho}{2}mH\tilde{x}_2 + \rho nH\tilde{x}_3 + \frac{\rho}{2}tH\tilde{x}_4$$

$$\therefore |AJ| = \frac{1}{W}\left[\frac{wh^2}{2H}m\tilde{x}_1 + \frac{\rho}{2}mH\tilde{x}_2 + \rho nH\tilde{x}_3 + \frac{\rho}{2}tH\tilde{x}_4\right] \quad (3.15)$$

Eccentricity, e, is given by

$$\therefore e = d - \frac{b}{2} \quad (3.16)$$

$$d = |AJ| + x \quad (3.17)$$

From similar triangle we have that,

$$x = \frac{P}{2} \text{x} \frac{h}{3} \quad (3.18)$$

When the dam is retaining water, the eccentricity is as given in equation 3.16, but when the dam is empty, the water pressure, P, is zero. Thus, $|AJ| = 0$, and the eccentricity becomes,

$$e = \frac{b}{2} - |AJ| \quad (3.19)$$

3.1.2). Total Stress at the Toe and Heel of the Dam.

$$\sigma_{max} = \frac{W}{b}\left(1 + \frac{6e}{b}\right) \quad (3.20)$$

$$\sigma_{min} = \frac{W}{b}\left(1 - \frac{6e}{b}\right) \quad (3.21)$$

Where;

The definitions of a, b, m, n, t, h, H, $, \beta, \theta,$ $|AJ|$, $|AQ|$, $|QD|$, $|QT|$, $|TB|$, $|TC|$, $|AT|$ and x, are as given in Fig 3.1.

ρ is the unit weight of the dam masonry in kN/m^3

ω is the unit weight of water, in kN/m^3

3.2: Stability Checks

3.2.1: Tension at the masonry base of the dam

For there to be no Tension at the masonry base of the Dam, the position of the resultant force acting on the dam must pass within the middle third of the base. That is the position of $|AJ|$must lie between $\frac{b}{3}$ and$\frac{2b}{3}$. Or the eccentricity must be less than or equal to $\frac{b}{6}$

$$\left(i.e. \quad e \le \frac{b}{6}\right) \quad (3.22)$$

3.2.2: Overturning of the Dam at the heel of the dam base.

For there to be no overturning at the toe of the dam base, the position of the resultant force acting on the dam must pass within the base

$$(|AJ| \le b). \quad (3.213)$$

There is a superfluous condition which is always satisfied once the condition for tension stability is met.

3.2.3: Check against Sliding Failure.

For there to be no sliding the maximum frictional force F_{max} must be greater than the water pressure at the upstream face of the dam masonry.

$$F_{max} = \mu W > P \quad (3.24)$$

Where μ is the coefficient of friction between the dam base and the foundation soil, in most practical conditions μ is taken 0.6. For safety of the dam against sliding, a minimum factor of safety(FoS) of 1.5 is allowed. The FoS is obtained by taking the ratio of the maximum frictional force to the total water pressure acting on the dam.

$$FoS = \frac{F_{max}}{P} \ge 1.5 \quad (3.25)$$

3.2.4: Check against Crushing of the Masonry Base.
For there to be no crushing of the masonry of the dam, the maximum stress at any part of the dam must be less than the allowable stress .

$$\sigma_{max} \leq \sigma_{all} \quad (3.26)$$

3.3: Analysis of the study section.

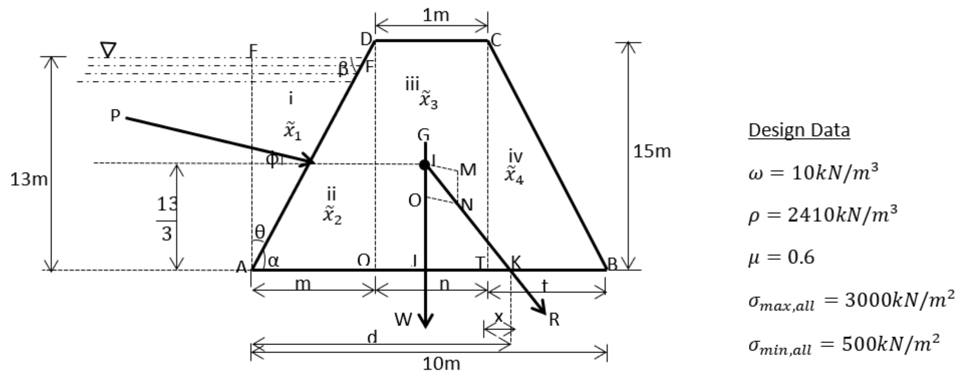

Fig. 3.2: The study section of a Trapezoidal Gravity Dam with a Symmetrical Width Variation.

Applying equations 3.1 to 3.26 to the appropriate combination of the geometrical dimensions, and parameters given table 3.1 for the study section, we obtain the results presented in the next section.

Table 3.1: Cross sectional Dimension of the symmetrical Trapezoidal Dam.

Case	a(m)	b(m)	m(m)	n(m)	t(m)	h(m)	H(m)	a as % of b	Eccentricity, e(m)
1	1	10	4.5	1	4.5	13	15	10	1.22
2	2	10	4.0	2	4.0	13	15	20	1.172
3	3	10	3.5	3	3.5	13	15	30	1.132
4	4	10	3.0	4	3.0	13	15	40	1.539
5	5	10	2.5	5	2.5	13	15	50	1.077
6	6	10	2	6	2.0	13	15	60	0.219
7	7	10	1.5	7	1.5	13	15	70	1.204
8	8	10	1.0	8	1.0	13	15	80	1.10
9	9	10	0.5	9	0.5	13	15	90	1.022
10	10	10	0.0	10	0.0	13	15	100	1.017
11	0	10	5.0	0	5.0	13	15	0	1.277

Table 3.1 displays the geometrical dimensions of the dam at various top widths, as shown in Figure 3.2. Applying the equations derived in section 3.2 to the various combinations of appreciate cross-sectional dimensions in Table 3.1, we have the results as presented in section 4.

IV. RESULTS AND DISCUSSIONS.

4.1). Stability against Tension

Table 4.1: Variation of AK with a and % variation

a(m)	AK(m)	(m)	%Variation
1	6.220	10	10

2	6.172	10	20
3	6.132	10	30
4	6.539	10	40
5	6.077	10	50
6	6.219	10	60
7	6.204	10	70
8	6.100	10	80
9	6.022	10	90
10	6.017	10	100
0	6.277	10	0

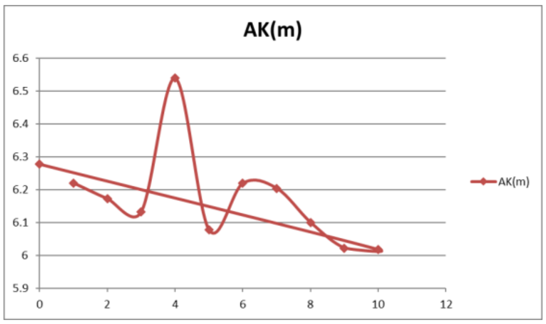

Figure 4.1: Variation of the position of the Resultant Force(AK) with the Top Width of the Dam(a).

Table 4.1 and Fig 4.1 give the position where the resultant force on the dam cuts the base. The total vertical and horizontal forces on the dam were calculated and the moments of all the forces about the heel of the dam were taken. The position where the Resultant Force cuts the base for each case was calculated, all of which lie within the middle third of the base(3.33m to 6.67m). The eccentricity in all the case were less than b/6(i.e., e < 6.67m) and hence, no tension would developed at any part of the dam base masonry. The results show that the smaller the top width in relation to the bottom width, the higher the eccentricity of the dam which will eventually imparted on the stresses developed on the dam masonry.

4.2). Stability against Overturning

The position where the Resultant Force cuts the base for all the cases studied passed through the base, since all of them lie within the middle third of the base(3.33m to 6.67m). In other words, since the stability of the dam against tension was satisfied, the stability of the dam against overturning is automatically satisfied, as this is a superfluous condition.

4.3 :Stability against Sliding

Table 4.2: Variation of a, with F_{max}, and P

a(m)	P(kN)	F_{max}(kN)	Factor of safety(FoS)
1	845	1340.1	1.59
2	845	1431.198	1.69
3	845	1522.302	1.80
4	845	1505.4	1.78
5	845	1704.50	2.02
6	845	2083.602	2.47
7	845	1886.7	2.23
8	845	1977.78	2.34
9	845	2068.896	2.45
10	845	2160.00	2.56
0	845	1249.002	1.48
			$FoS_{Avg} = 2.07$

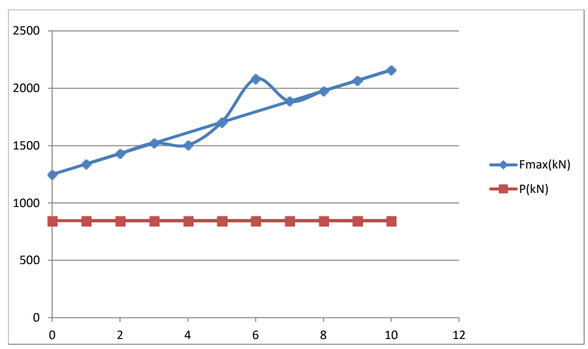

Figure 4.2: Variation of the Maximum Frictional Force($\boldsymbol{F_{max}}$) and the maximum water pressure(P), with the Top Width of the Dam(a).

From the given results in Table 4.2 and Fig 4.3, the dam has a good factor of safety (FoS) against Sliding, with an average FoS of 2.07, an indication that gravity dam due to their compactness and self-weight can offer a good resistance against Sliding failure. The results also reveals that the geometry of the dam has a role to play in it's stability, as the rectangular dams(case 10) are more stable than dams of other geometrical shapes, followed by trapezoidal dam section. Triangular dam section has the least performance in terms of sliding as can be seen in case

10 when the top width is zero (i.e., a = 0). The optimum top width for the trapezoidal section was found to be 60% of the bottom width. In real life, dams of Trapezoidal sections are generally more common, because they are more economical in terms of material requirements. Triangular dam (case 11) has shown not to offer a good resistance to sliding as it's FoS is less than 1.5, this might be the reason why triangular dams are not common in real life.

3.4) against Crushing:

Table 4.3: Variation of a, with σ_{max}, and σ_{min}.

a(m)	$\sigma_{max}\ kN/m^2$	$\sigma_{min}\ kN/m^2$
1	386.84	59.86
2	406.269	70.796
3	426.042	81.32
4	482.58	19.22
5	467.66	100.51
6	392.898	301.636
7	541.61	87.
8	547.90	112.06
9	556.26	133.37
10	579.67	140.33
0	67.66	48.67

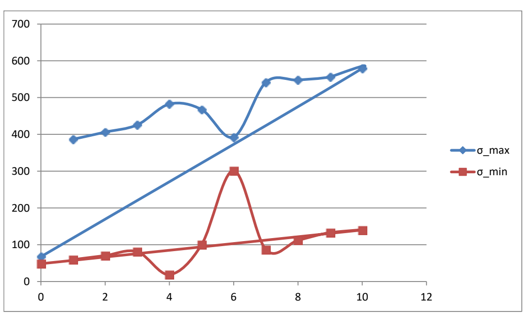

Figure 4.3: Variation of the Maximum stress(σ_{max}). and Minimum stress()σ_{min} with the Top Width of the Dam(a).

The maximum stress at the toe of the dam is found to be 579.67 kN/m2, which is less than allowable concrete compressive stress of 3000 kN/m2; and 140.33 kN/m2 at heel, which is less than the allowable concrete tensile stress of 500 kN/m2. All the stresses calculated at toe and heal of the dam are found to satisfy the conditions of safe design. The study reveals that the maximum stress at the toe and at the heel of the dam increases with increasing top width. The optimum top width for the trapezoidal section was found to be 60% of the base width. The study also reveals that the rectangular section is better than the trapezoidal section in terms of stability against Crushing, as can be seen in case 10 when both the top width and the bottom width equals each other.

CONCLUSIONS AND RECOMMENDATIONS

5.1: Conclusions:

From the results of the study, we hereby make the following conclusions;

- That the ratio of the top width of the dam in relation to the bottom width plays a big role in the stability of the gravity dam section.
- The rectangular gravity dam section(case 10) is the most stable when compared to dams of other sections considered, namely triangular (case 11), and trapezoidal (other cases except 10 and 11). However, for economic reasons, the trapezoidal dams are more common as they offer reduction in material requirements.
- The trapezoidal dam section is more efficient compared to the triangular dams, stressing the reason why triangular dams are not common in practice.
- The study also reveals that 0.6(i.e 60%) is the optimum top/bottom width ratio.
- Generally, gravity dams are effective in resisting the imposed loads acting on the dam. This is further buttressed by the fact that the dam studied passed all the stability requirements for a dam, namely; stability against Tension, overturning, sliding and crushing.

5.2: Recommendations

We recommend the following;

- Further research on the effect of unsymmetrical top width variation on the Stability of gravity dams.
- Further study on the effect of height variation on the Stability of dam

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