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Analysis and Design of Gravity Dam by Using STAAD Pro Software.

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Abstract: *Gravity dams are massive hydraulic structures that resist external forces primarily through their self-weight and are widely used for water storage, irrigation, flood control, and power generation. This project presents the analysis and design of a concrete gravity dam using both manual analytical methods and STAAD.Pro software to evaluate its structural safety and stability. The study considers all major forces acting on the dam, including self-weight, hydrostatic pressure, uplift pressure, silt pressure, wave pressure, and seismic forces. Stability checks were carried out for critical loading conditions such as reservoir empty, reservoir full with uplift, and reservoir full without uplift.*

Manual calculations were performed to determine base width, stress distribution, and factors of safety against sliding, overturning, compression, and tension, in accordance with standard design principles and IS codes. The dam was then modeled and analyzed using STAAD.Pro, and the results were compared with manual computations for validation. The analysis showed that the resultant forces lie within the middle third of the base in all cases, indicating no tension at the foundation. The factors of safety obtained were within permissible limits, and the stress and displacement values were found to be acceptable.

The study concludes that the proposed gravity dam section is structurally stable, safe, and economical, and that STAAD.Pro is an effective tool for validating manual design and improving accuracy in gravity dam analysis.

Keywords*:* Gravity Dam, STAAD.Pro, Structural Analysis, Stability Analysis, Uplift Pressure, Sliding, Overturning, Stress Distribution, Finite Element Method, Dam Safety

I. INTRODUCTION

Dams are constructed across rivers to store water for irrigation, water supply, flood control, and power generation. Among various types of dams, gravity dams are widely used due to their stability and long service life. A gravity dam resists external forces mainly by its own weight and is usually constructed using concrete or masonry. The design of gravity dams requires careful consideration of various forces acting on the structure to ensure safety against failure. With advancements in software tools such as STAAD Pro, detailed analysis and optimization of dam structures have become more efficient and reliable.

II. LITERATURE SURVEY

1. ANALYSIS OF PRESSURE ON NAGARJUNA SPILLWAY.
(M V S S Giridhar, Madaka Madavi, Ramaraju Anirudh, E Ramakrishna) Goud to determine the pressure forces acting on the dam. Nagarjuna Sagar Dam. Water pressure is the major pressure rather than the remaining pressures.

2. DESIGN AND STABILITY ANALYSIS OF GRAVITY DAM USING STAAD PRO.
(Gaurav Sharma Abhay Joshi). To analyze the gravity dam using STAAD Pro Example Problem Mentioned, acquired forces, moments, deflections, element, and node count are used

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3. STUDY ON THE DAM AND RESERVOIR, ANALYSIS THE FAILURES OF DAM.
Mohith Kumar Bharati Mani Sharma (Mr. Nazrul Islam). To study the reservoir and avoid the failures of the dam Review Paper. Highlighted the different general aspects of dams, their types, and the cause of failure. And giving the data previously failed the dam in the world.

III. OBJECTIVE OF THE STUDY

The main objectives of this study are:

- To convert an existing earthen dam into a concrete gravity dam.
- To reduce the bottom width and achieve an economical dam section.
- To evaluate forces acting on the gravity dam under different reservoir conditions.
- To analyze the stability of the dam against sliding, overturning, compression, and tension.
- To compare manual calculations with STAAD Pro analysis results.

The objective of this project is to design an economical and stable gravity dam by reducing the base width while ensuring safety. The conversion of an earthen dam into a gravity dam helps to control seepage and piping problems. Gravity dams provide greater strength, durability, and stability compared to earthen dams. They also offer higher safety as they show warning signs before failure and require lower maintenance.

Fig.1 NARIHALLA DAM

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Fig.2 CREST GATES

Fig 3 IRRIGATION CENTRAL ZONE, MUNIRABAD OFFICE

CALCULATION OF VOLUME

Bottom Width = 143.601 m, Height = 30.92 m, Top Width = 3.66 m, Lenth = 295 m – 55.47= 239.53 m Total volume: 545327 $m3$ Maximum water Storage: 22.92 cume Usable Storage: 20.86 cume.

IV. METHODOLOGY

The methodology adopted in this study includes:

1. Collection of dam geometry and site data.
2. Manual calculation of forces acting on the dam.
3. Stability analysis for different reservoir conditions.
4. Modeling of the gravity dam in STAAD Pro.
5. Application of loads and load combinations.
6. Analysis of stresses, moments, and deflections.
7. Comparison of software results with manual calculations.

1.Initial Stage: Analysis & Design of Dam The first step involves gathering all necessary parameters for dam design, including site conditions, dam type (e.g., gravity, earthen), material properties, and functional requirement.

CALCULATION OF GRAVITY DAM

The minimum base width required for the elementary profile should be the greater of the values obtained

$$C = 0 \; B = \frac{H}{\sqrt{G-C}} = \frac{30.92}{\sqrt{2.4-0}} = \mathbf{19.95}$$

$$C = 1 \; \frac{30.92}{\sqrt{2.4-1}} = \mathbf{26.132}$$

RANGE OF BASE WIDTH OF AN ELEMENTARY PROFILE

$$B = \frac{H}{\sqrt{G-C}}$$

If C = 0, G = 2.40, we have B = 0.65 H C = 1.00, G = 2.4, we have B = 0.85 H B = 0.65 x 30.92 = 20.098

B = 0.85 x 30.92 = 26.282. It is observed that the value of B various from 0.64 to 0.95 times H. In actual practice, base width usually various between 0.7 H to 0.8 H. The slope of D/s face is, therefore, from 0.7: 1 to 0. 8: 1 in most cases.

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Limiting Height of a Low dam

We are considering low gravity dam because

$$\text{Limiting height} = Hcr = \frac{fa}{w\,(G-C+1)}$$

When C = 0 f = 3000, w = 9.81, C = 0, G = 2.4

$$Hcr = \frac{fa}{w\,(G-C+1)} = \frac{3000}{9.81\,(2.4-0+1)} = \mathbf{89.94}$$

C = 1, = 90 m

Condition:

a) For Low dam. H < Hcr

b) For High dam H > Hcr

So, 30.92 < 90 {Low dam)

Desing of Gravity Dam

Base Width

$$B1 = \frac{H}{\sqrt{Sc-C}} = \frac{31}{\sqrt{2.4-1}} = 26.197$$

$$H' = 2a\sqrt{Sc - C}$$

$$= 2 \times 4.5\sqrt{2.4 - 1}$$

$$= 10.648$$

$$B = 0.85 \times H$$

$$= 0.85 \times 31$$

$$= 26.35$$

$$\emptyset = tan^{-1} = \frac{21.69}{23.2} = 43.07$$

FORCE ACTING ON GRAVITY DAM

1) SELF WEIGHT:

W1 = ½ x b x h x density

= ½ x 0.27 x 20.36 x 2.4

= 65.96 kN

W2 = b x h x density

= 4.5 x 31 x 2.4

= 3348kN

W3 = ½ x b x h x density

= ½ x 21.58 × 23.2 × 2.4

= 6007.87 kN

Total self-weight = W1 +W2 +W3 = 9421.83 kN

2) WATER PRESSURE

= ½ x W x *h*2 [Horizontal force]

= ½ x 9.81 x 28.1752

= 3845.52 kN

Vertical force = ½ x b x h x w

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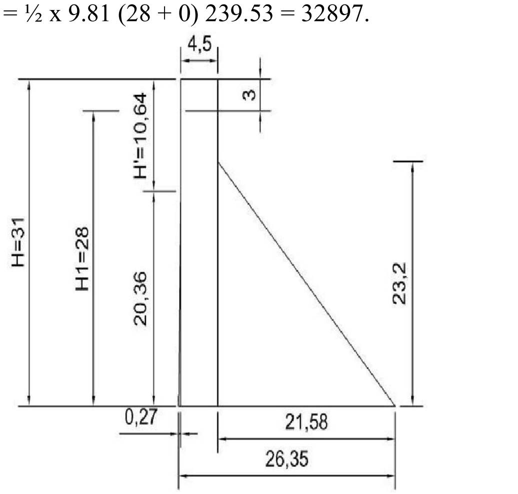
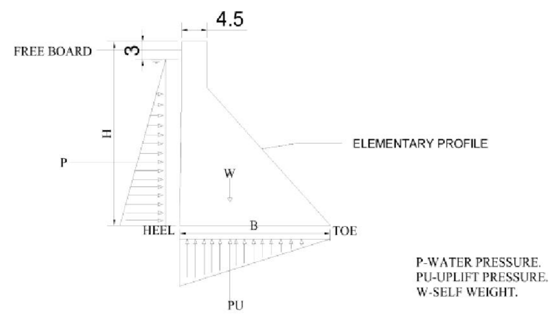
= ½ x 0.27 x 31 x 9.81
= 41.05 kN

3) WAVE PRESSURE:
$0.0322\sqrt{FV}$
F = Petch
V = wind velocity
$=0.0322\ \sqrt{32\ x\ 17.8}$
= 0.768 kN

4) UPLIFT FORCE:
Without a drainage gallery, the uplift pressure varies linearly from γwH (upstream) to γw H' (downstream) & the total uplift force under the base.
Lenth of the dam: 295 m
Crest gate: 55.47 m 295-55.47 = 239.53 m
Pu = ½ γw (H + H') L
= ½ x 9.81 (28 + 0) 239.53 = 32897.



DIMENSIONS OF GRAVITY DAM.



ALL DIMENSIONS ARE IN METERS.

SL no	Items	Description & dimension	Forces (kN) Vertical	Forces (kN) Horizontal	Lever arm from toe (m)	Moment about toe (+)	Moment about toe (-)
1.	W1	0.5 X 0.27 X 20.36 X 24	65.96	_	26.17	1726.17	_
2.	W2	4.5 X 31 X 24	3348		23.83	7978284	
3.	W3	0.5 X 21.58 X 23.2 X 24	6007.87	_	14.38	86393.17	
4.	PH	9.81 X 1 X 28^2 2		3845.52	9.33		35891.52
5.	Pv1	0.27 x 10.64 x 10	28.72		26.21	738.73	
6.	Pv2	0.5 x 0.27 x 20.36 x 10	27.48		26.26	707.96	
7.	PU	0.5 X 26.35 X 28 X 10	-3689		17.56		64778.84

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		+9421.83 +56.2 -36.89 =5789.03				+16790218 +1446.69 =169348.87	-100670.36

CASE'S ACTING ON GRAVITY DAM

1. when the reservoir is empty.
2. when the reservoir is full considering uplift.
3. when the reservoir is full without considering uplift Case 1: When Reservoir Empty Condition

• Position Of Resultant from Toe:

$$\bar{x} = \frac{\Sigma M1}{\Sigma V1} = \frac{167902.18}{9421.83}$$

$\bar{x}$ =17.82 m

$e = 0.5\ \bar{B} - \bar{x} = 0.5 \times 26.35 - (17.82) = -4.64$

As Per e < B / 6 = - 4.64 < 26.35 = 4.39

6

-4.64 < 4.39

The Resultant falls to the left of the centre

- Vertical stress at the toe,

$$\text{fyd} = \frac{\Sigma v1}{b}\left(1 + \frac{6e}{b}\right) \quad \text{fyd} = \frac{9421.83}{26.35}\left(1 + \frac{6 \times (4.64)}{26.35}\right) \quad = \textbf{fyd} = \mathbf{-20.21\ kN / m^2}$$

- Vertical stress at the toe, $\text{fyu} = \frac{\Sigma v1}{b}\left(1 - \frac{6e}{b}\right)$ $\text{fyu} = \frac{9421.83}{26.35}\left(1 - \left(\frac{-46.64 \times 6}{26.35}\right)\right)$ = **fyu = 735.34 kN / m^2**

- Principal stress at the toe

$$\sigma d = \text{fyd} \times \sin^2\emptyset d \qquad \sigma d = -20.21 \times [1 + 0.8^2) \quad = \boldsymbol{\sigma d = -33.14\ kN / m^2}$$

- Shear stress at the toe Td = fyd x tan$\emptyset d$ Td = -20.21 x 0.8 =**Td = -16.16 kN / m^2**
- Principal stress at the heel $\sigma u = fyu \times \sin^2\emptyset u$ Tu = 735.34 x (1 + $(0.1)^2$ = Tu = +742.69 kN / m^2

Shear stress at the heel

Tu = -fyu x tan$\emptyset u$ = -735.31 x 0.1 = -73.53 kN / $\boldsymbol{m2}$ (Towards Downstream)

Cheak for Tension Since e < B/6, there is not Tension

Cheak for Sliding Since there is not Force, Sliding will not occur.

Case 2: Check forces the Reservoir full Condition Considering uplift. In this case all the forces to will act.

$$\bar{x} = \frac{\Sigma M}{\Sigma V} = \frac{169348.87 - 100670.36}{5789.03} = \mathbf{11.86}$$

$e = 0.5\ \text{B} - \bar{x} = 0.5 \times 26.35 - (11.86) = \mathbf{1.315}$

As Per e < B / 6

1.315 < 4.39

Vertical stress at the toe, $\text{fyd} = \frac{\Sigma v}{B}\left(1 + \frac{6e}{B}\right)$

$$\frac{5789.03}{26.35}\left(1 + \frac{6 \times 1.315}{26.35}\right)$$

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fyd = 285.48 kN / $m2$

Principal stress at the toe = 285.48 x [1 + 0.82) = 468.18 kN / $m2$

Shear stress at the toe = 285.48 x 0.8 = 228.38 kN/ $m2$

Vertical stress at the heel $f_{yu} = \frac{\Sigma v}{B}(1 + \frac{6e}{B})$

$\frac{5789.03}{26.35}(1 - \frac{6 x 1.315}{26.35})$

fs 1.12 > 1.00

Cheak for overturing

$f_o = \frac{\Sigma MR1}{\Sigma M0} = \frac{169348.87}{100670.36}$

fo = 1.68 > 1.50

3. Check Fore the res full condition, considering no uplift

In this case only the forces (1) to (6) act

$\bar{x} = \frac{169348.87 - 35891.52}{56.2}$ $\bar{x}$ **=2374.68**

e = 0.5 B - $\bar{x}$ = 0.5 x 26.35 – (2374.68) = - **2361.50 m**

As Per e < B / 6 **-2361.50 < 4.391**

Vertical stress at the toe,

$fyd = \frac{\Sigma v}{B}(1 + \frac{6e}{B}) = \frac{56.2}{26.35}(1 + \frac{6 x (-2361.50)}{26.35})$ **fyd = -1149.003 kN / m^2**

Principal stress at the toe

σd =(- 1149.003 x 1.64) = -1884.36 kN / $m2$

Shear stress at the toe

Td = (- 1149.003 x 0.8) = 919.20 kN / $m2$

Vertical stress at the heel $fyu = \frac{\Sigma v}{B}(1 + \frac{6e}{B}) = \frac{56.2}{26.35}(1 + \frac{6 x (2361.50)}{26.35})$=**fyu = -189.01 kN / m^2**

Principal stress at the heel

σu = -189.01 x 1.01 =σu = -190.90 kN / $m2$

Shear stress at heel,

Tu = -189.01 x 0.1 = Tu = -189.901 kN / $m2$

Cheak for tension since e < B / 6, there in no tension.

Cheak for sliding fs = $u\Sigma v$ = 0.75 x 56.2 fs = 0.01 = fs 0.01> 1.00

Cheak for overturing: fo = $\Sigma MR1$ = 169348.87 = fo = 4.71

V. ANALYSIS AND DESIGN USING STAAD PRO

The gravity dam was modeled as a three-dimensional structure in STAAD Pro. Material properties and boundary conditions were assigned as per standard design practices. Loads such as water pressure, uplift pressure, and self-weight were applied to the model. The analysis was performed for three cases:

Step 1: Develop a node centre. With required dimension, and entered the average concentration in the STAAD log. Step 2: Select the plate option and display the plate. I used the plate upload order to draw a plate. Step 3: 3D view of the

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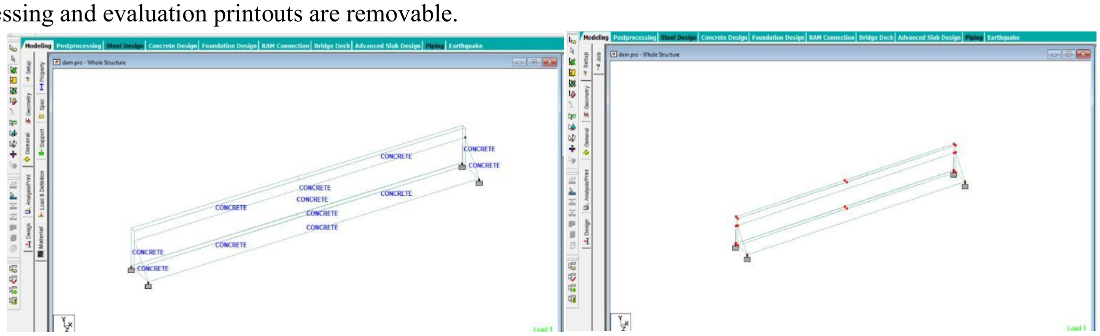
structure. Here it was shown that the momentary intermittent requirements of the Y bearing were used to obtain the 3D coefficients of the view of the structure.

Step 4: Descending support and assets. After creating the structure, the beams are determined to be fixed based on layout inspiration. In addition, the material was specified and the segment of the plate diagram was changed to variance.

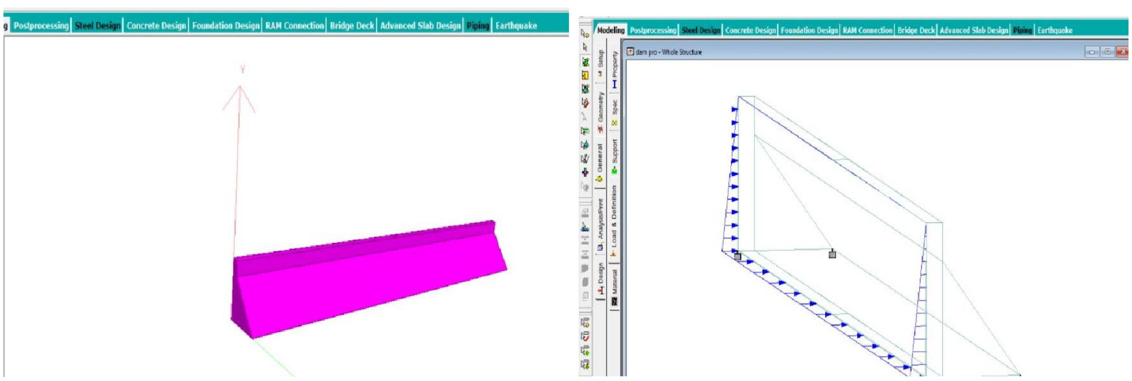
Step 5: 3D conveyor view. You can name the asset to see the 3D promotion factors for improvement. Step 6: Assign the material properties.

Step 7: Weight Mixture Descent DL + LL, DL + LL + UPL, DL worldwide diary of pure and applied science Exceptions with safety factors and accuracy Directional of load X, Y, Z.

Step 8: Use STAAD's proven software program for the evaluation part and assign all required parameters. IS 456: 2000 and SP 16: 2000 are codebooks. Step 9: Hold and run the record for printing the report. Check the number of errors that occurred in this process of the dam. If you get no results, you can change it to find out what went wrong. Final processing and evaluation printouts are removable.



NODES & MATERIAL ASSINGED TO THE STRUCTURE



3D VIEW AND LOAD ASSIGNED TO THE STRUCTURE

VI. RESULTS AND DISCUSSION

The analysis results showed that:

- The dam is safe against overturning in all loading conditions.
- Sliding stability is satisfactory when uplift pressure is properly considered.
- No tensile stress was observed as the resultant force lies within the middle third of the base.
- Results obtained from STAAD Pro closely match manual calculations, validating the analysis approach.

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VII. CONCLUSION

The present study successfully demonstrates the analysis and design of a concrete gravity dam using STAAD Pro. Converting the earthen dam into a gravity dam resulted in improved stability and reduced structural volume. The dam was found to be safe against sliding, overturning, compression, and tension under all considered loading conditions. The use of STAAD Pro proved effective in validating manual calculations and optimizing the dam design. Gravity dams are therefore recommended for long-term durability and safety in suitable geological conditions.

REFERENCES

[1] S. S. Tarek, V. V. Tolstikov, "World experience in the construction of gravity dams using particularly lean concrete mix," Construction Materials and Products, Vol. 4, No. 2, 2021.

[2] Mettu Rajesh Reddy, M. Nageshwar Rao, "Design and Analysis of Gravity Dam – A Case Study Analysis Using

[3] STAAD.Pro," International Journal of Engineering Research, Vol. 2, Issue 4, 2017.

[4] A. Fathi, "Dynamic analysis of weight concrete dams using combined finite element and boundary element methods," M. Tech Thesis, Amir Kabir University of Technology, Iran, 2004.

[5] M. Akkose, E. Simsek, "Non-linear seismic response of concrete gravity dams to near-fault ground motions including dam–water–sediment–foundation interaction," Applied Mathematical Modelling, Vol. 34, pp. 3685–3700, 2010