FEA ANALYSIS of GRAVITY DAM

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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 concrete. Basically, a gravity dam concrete dam is defined as a structure, which is designed in such way that its own weight resists the external forces. It is primarily weight gravity dam which prevents it from overturned when subjected to the thrust of impounded water.

In current paper sample case study has been validate against the analytical and FEA solution. Water pressure and weight of dam is considered for analysis. Unit length of dam is considered for analysis purpose. Also analytically it has been tested for different factor of safety. ANSYS 14.5 is used for FEA analysis.

Keywords:Center of gravity, Gravity dam, hydrostatic pressure,Masonry etc.

I. INTRODUCTION

A dam is a hydraulic structure constructed across river to store water on its upstream dam. It is an impervious or fairly impervious barrier put across a natural stream so that reservoir is formed. This water is then utilized as and when it is needed. Due to the construction of dam, water level in the river at its upstream side is very much increased. Highest dams in the world are made of gravity dams only. Masonry gravity dams are now days constructed of only small heights. [1]

1. Advantages:

- Gravity Dams are relatively more strong and stable.
- A gravity dam requires least maintenance.
- A gravity dam is cheaper in the long run since it is more permanent that any other type.
- Gravity dam can be constructed of any heights, provided suitable foundation is available to bear stress.

2. Disadvantages:

- They can be constructed on only sound rock foundation. They are unsuitable for weak foundation.
- Initial cost of gravity dam is high.
- Gravity dam require skilled labour.

3. Analysis considerations:

Forces acting on gravity Dam

- Water pressure
- Weight of Dam
- Uplift pressure
- Pressure due to earthquake
- Ice pressure
- Wave pressure
- Silt pressure
- Wind pressure. [1]

For analysis purpose we have consider the following 2 forces.

- Water pressure
- Weight of dam

- **Water pressure**: This is major external force acting on dam. When the upstream face of the dam is vertical, the water pressure acts horizontally. The intensity of pressure varies triangular with a zero intensity at the water surface, to a value (ρ *g* h) at any depth h below water surface.

Where

ρ = Density of water = 1000 kg/m^3

g = Acceleration due to gravity = 9.81 m/s^2

h= Height of water

- **Weight of dam**: The weight of Dam is major resisting force. For analysis purposes, generally unit length of the dam is considered. The cross section can then be divided into rectangles and triangles. The weight of each along with their CG (Center of gravity) can be determined. The resultant of all these downward forces will represent the total weight of the dam acting at the CG of the dam.

- **Material**: Masonry with density = 2500 kg/m^3, weight density = 24.5 kN/m^3,compressible strength = 3000kN/m^2

- **Problem definition**: A masonry dam trapezoidal in cross section is 4 m wide at the top 8 m wide at the base and 10 m high. It retains the water level top against a vertical face. [4]

Assumption:

1. Only water force and weight of dam is considered for analysis purposes.

2. Unit length is analysis purpose
3. The materials in dam body and foundation are isotropic and homogeneous.

II. ANALYTICAL SOLUTION:

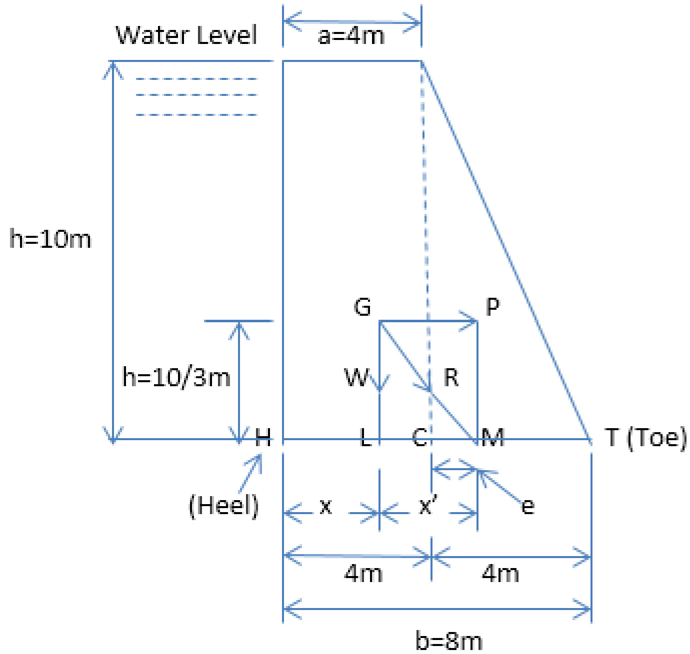

Fig. 1: Gravity Dam

Weight of masonry acting through cg:

$$W= \frac{8+4}{2} * 10*1*24.5 = 1470 \text{ kN}$$

Water pressure:

$$P = \frac{\rho g h^2}{2} = \frac{9.81*10*10}{2} = 490.50 \text{ kN}$$

Let x be the distance of cg from vertical face. Dividing the trapezium rectangle and triangle and taking moments about the vertical face, we have

$10*4*(4/2) +\frac{1}{2}*10*4(4+\frac{4}{3}) = (10*4+ \frac{1}{2}*10*4) * x$

x = 3.11 m

From figure 1

$\tan\alpha = \frac{P}{W} = \frac{490.5}{1470}$ -----1

Also

$\tan\alpha = \frac{x'}{10/3}$ -------2

Solving 1 and 2 we get, x' = 1.11m

Now x + x' = 3.11 + 1.11= 4.22m

1.22 $< \frac{2}{3}\, 8$

Therefor dam is safe as it satisfy the above condition.

Eccentricity of resultant thrust

e = x + x' – 4 = 4.22-4 =0.22m

Bending stress:

$$\sigma_b = \frac{M}{I} y$$

Where,

W= Weight of the dam

I = moment of inertia

Y = distance = b/2

$$\sigma_b = \frac{(W*e)\,y}{I} = \frac{1470*0.22*4*12}{\frac{1*8^3}{12}} = 30.3 \text{ kN/m}^2$$

$$\text{Direct stress} = \frac{\text{weight of masnory}}{\text{Area of base}} = \frac{1470}{8*1}\ 183.7 \text{ kN/m}^2$$

$$\sigma_{max} = \sigma_d + \sigma_b = 183.7+30.3 = 214 \quad \text{kN/m}^2$$

$$\sigma_{min} = \sigma_d - \sigma_b = 183.7-30.3 = 153.4 \quad \text{kN/m}^2$$

1. The factor of safety against the sliding = $\frac{\mu W}{P} = \frac{0.7*1470}{490.5}$ =2.09 (This should be greater than 1)

2. To avoid failure due to tension and compression Direct stress> Bending stress.

(183.7 > 30.3)

3. Factor of safety against overturning =$\frac{W(b-x)}{P*\frac{h}{3}} = \frac{1470\,(8-3.11)}{490.5*\frac{10}{3}}$ = 4.39

This factor of safety against overturning should be greater than 1.

All the criteria satisfy the condition so current dam is safe against the sliding and overturning. Also all the stresses are within compressive limit of material.

III. ANSYS WORKBENCH SOLUTION

1. Geometry:

For given dimensions geometry has been created in software as shown below.

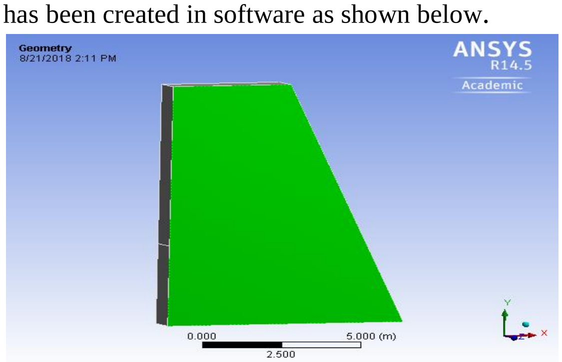

Fig. 2: Geometry of model

2. Mesh:

Quadrilateral mesh has been generated for element size 0.22.

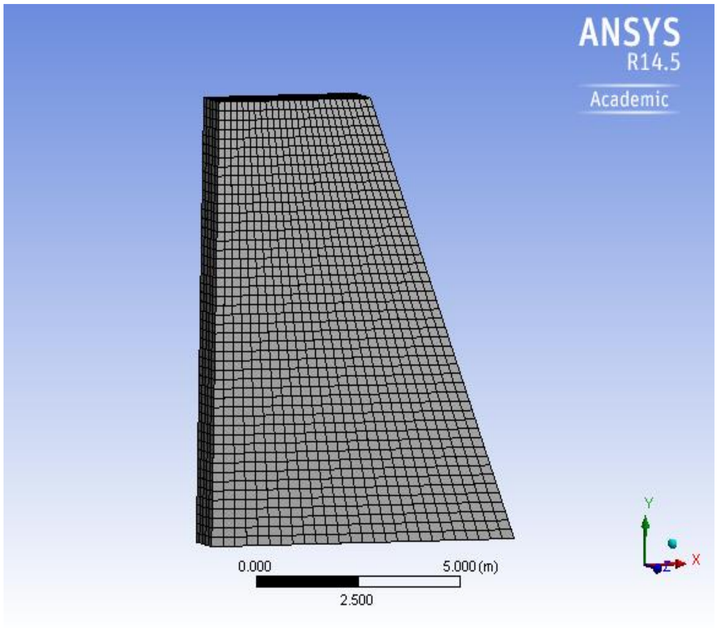

Fig. 3: Mesh of the model

3. Force: standard earth gravity:

Application of the standard earth gravity force in negative y-direction.

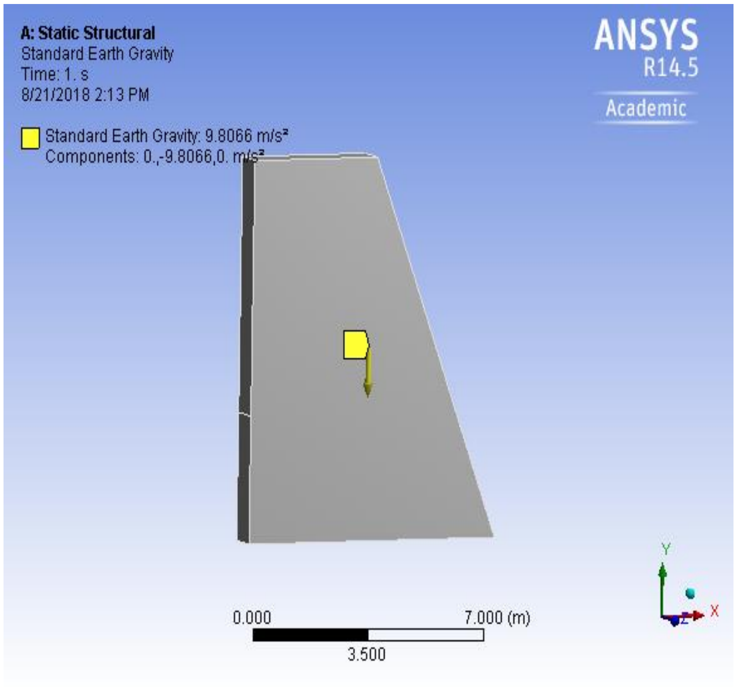

Fig.4: gravity force application

4. Force: hydrostatic pressure:

Application of hydrostatic force varying from 0 to 10 m height as shown in fig.5.

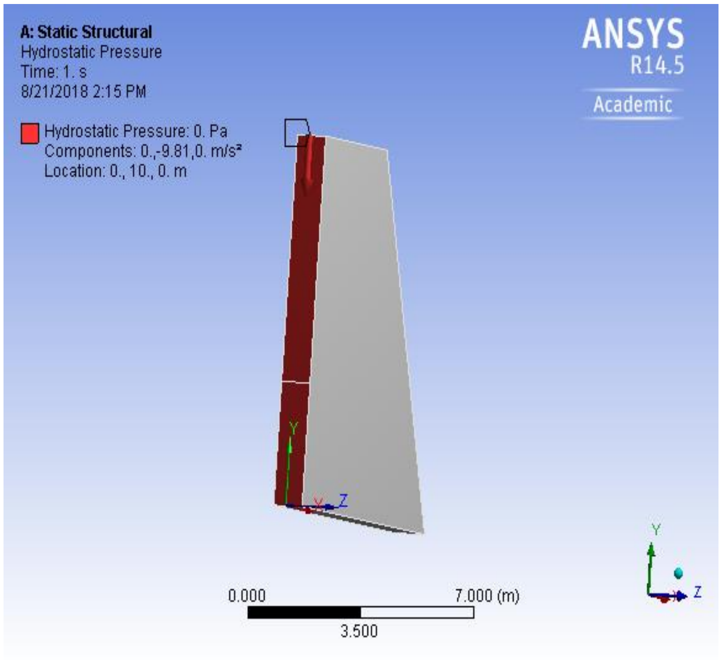

Fig.5: Hydrostatic pressure

5. Fixed support at bottom:

Bottom surface of geometry has been treated as fixed support as shown in fig.6.

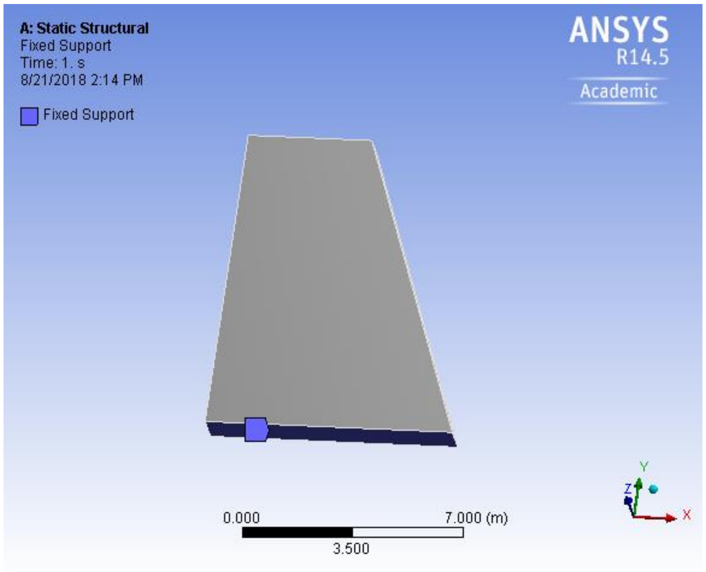

Fig.6: Fixed support at bottom

6. Normal stress:

Fig.7 shows Normal stress distribution for given dam geometry.

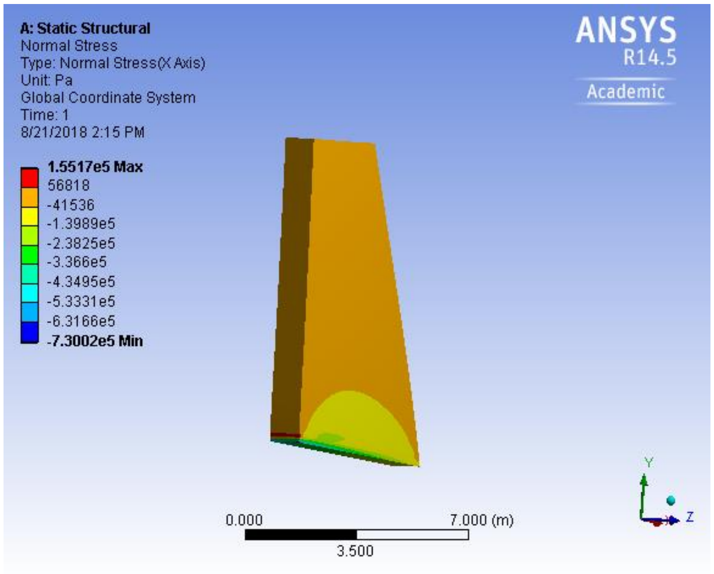

Fig.7: Normal stress distribution

IV RESULT AND DISCUSSION

Normal stress value is in FEA is 155 kN/m^2 and analytical value is 183 kN/m^2. Error is 13 %. Since factor of safety is greater than 1 thereforecurrent configuration is also satisfying the criteria for sliding and overturning.All the criteria satisfy the condition so current dam is safe against the sliding and overturning. Also all the stresses are within compressive limit of material.

V CONCLUSION

FEA and analytical results are within 13 % error by considering water pressure and weight of dam.

For the simplification purpose we have consider only water pressure and weight of dam but for better analysis one can consider the all the forces acting on dam (i.e. Water pressure, Weight of Dam, Uplift pressure, pressure due to earthquake, Ice pressure, Wave pressure, Silt pressure and Wind pressure.) and can verify the stress value. This stress value should be within compressible limit of material. As well as one should verify the factor of safety against sliding and overturning.

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