CONCRETE GRAVITY DAM STABILITY ANALYSIS

Mrs.V.Srujana [1] , Ms.J.Divya [2], Mrs. M.Durga [3]
Department of Civil Engineering, Samskruti College of Engineering and Technology

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Abstract:

Gravity dams are the lifesaving mega structures which are mainly used for irrigation, hydroelectric power generation, water supply, water animal enhancement etc.., the concrete gravity dams has to maintain its stability by its own weight. The strength of the material is important when the concrete gravity dam is analyzing stability and the seismic pressure.

This project basically gives the analysis of stability of concrete gravity dam by using STAAD.pro and conventional methods. STAAD.pro is computer software, which is used for stability and stress analysis of structures. Dam is such a massive structure; to evaluate such structure manually is very tedious and long timing process so it's easy to evaluate the dam stability STAAD.pro.

Keywords: Gravity dam, concrete, moments, frictional force, stability, STAAD Pro v8i

Introduction:

This paper presents the basic guideline for stability analysis of concrete gravity dam. The gravity dam has to maintain its stability against the loads from its structural mass and strength of concrete. The loads assumed on the concrete dam for stability analysis are water pressure, uplift force, wind force, wave pressure, silt pressure, self weight. To withstand the stability of concrete gravity dam, the dam has to be safe with the overturning force on dam, sliding force, compression and tension. Concrete gravity dam has the many load combinations such structures has to maintain its stability when the dam having the different proportions of water level (a) when the reservoir is empty, (b) When the reservoir is half filled, (c) When the reservoir is fully filled to the dam base and (d) Also when the uplift pressure on the dam. The concrete gravity dam gets cracks easily by its upstream and downstream sides of the dam because of internal and external temperature changes and by earthquakes. This

cracks causes to the failure of the dam in the static and dynamic conditions of the dam.

The forces that acting on the gravity dam with the

Water pressure: The hydraulic pressure is a horizontal force, acts on the dam in the form of triangular shape. At the surface of reservoir the water exerts no pressure and at the bottom (at toe) the water exerts maximum amount of pressure to dam.

Water pressure = ½ $\gamma_w.h^2$, acts on $\frac{h}{3}$ height from the water base.

Uplift pressure: The water seeping through the cracks, pores, fissure of the foundation material. Then the water seeps through the bottom joints of the dam structure and the foundation of the dam. Water exerts an uplift pressure on the dam base. The uplift pressure is depend on the height of water, the water level is maximum then the uplift pressure is also maximum. The uplift pressure at the toe is calculated by $\gamma_w.h$.

Silt pressure: The silt get deposited to the upstream side of the water. The weight and the pressure of the submerged silt are to be considered in addition to weight and pressure of water. The weight of the silt acts vertically on the slope and pressure horizontally. It is compute by the Rankin's formula.

Silt pressure $P_{silt} = {}^1/_2\ \gamma_{sub}\ h^2 k_a$

Where k_a is co efficient of the silt $= \frac{1-\sin \emptyset}{1+\sin \emptyset}$

$\emptyset$ Is angle of internal friction of soil.

Wave pressure: Generally the waves are generating on the surface of the reservoir by the wind blows. This causes pressure on the dam. Wave pressure is depends on the height of the wave.

$P_w = 2.4\ \gamma_w.\ H_w$

Weight of The Dam: The weight of the dam body and its foundation is the major resisting force. In two dimensional analysis of a gravity dam, a 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 centers of gravity can be determined. The resultant of all these downward forces will represent the total weight of the dam acting at the center of gravity of the dam.

Self-weight S_w = lbh.ρ_c.g

Where ρ_c is density of concrete= 2400 $\frac{kg}{m^3}$

Overturning stability: The overturning stability is calculated by calculating the all vertical force and the horizontal force acting on the gravity dam. By taking moments over toe, which forces are opposing the dam to overturn like self weight this moment as favorable moments (Mf) and the forces which are trying to overturn the gravity dam like water pressure, uplift pressure, wave pressure, silt pressure etc.., this moment as opposing moments (Mo) The overturning forces

should be more the 2, if it less than 2 the dam isn't safe.

Overturning moment = Mo/Mf. > 2

Sliding force: The stability of the gravity dam is loss by sliding. The excess of sliding is occurs in the time of earth quake. Sliding force refer the contraction between the dam foundation and rock. It is calculated by the frictional force and horizontal forces on the dam, it should not be less than 1.5.

Sliding force = frictional force/ horizontal force on dam. > 1.5

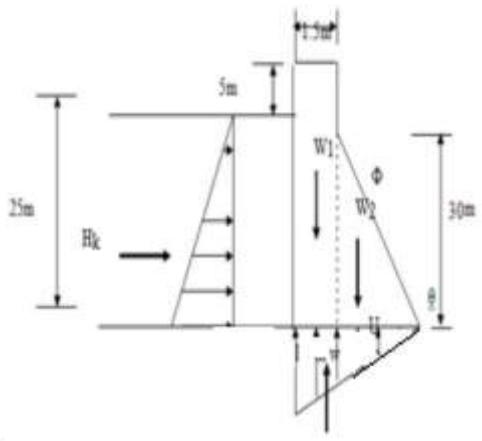
About STAAD Pro v8i:

Literature review:

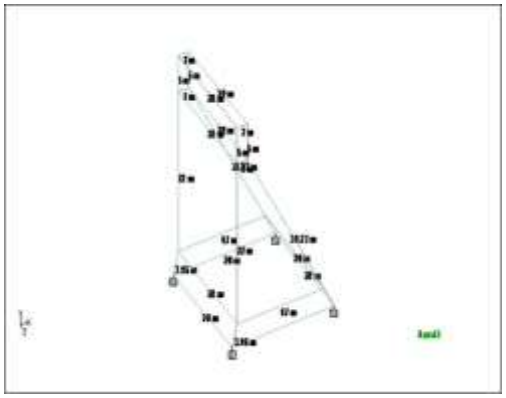
1. "Comparison of Design and Analysis of Concrete Gravity Dam" by Md. Hazrat Ali, Md. Rabiul Alam in 2011.

In this paper mainly tells about the dam stability with the different earthquake intensities, the increase of horizontal intensities the dam stability will decrease. The finite element method is used for calculation. Sufficient base width, adequate strong rock foundation, drainage gallery to reduce uplift pressure, silt pressure, and construction Joints need to be ascertained to improve factor of safety against sliding. Finally, it can be concluded that it would not be feasible to construct a concrete gravity dam for kh values greater than 0.3 without changing other loads and or dimension of the dam and keeping provision for drainage gallery to reduce the uplift pressure significantly.

2 "Seismic and Stability Analysis of Gravity Dams Using STAAD PRO" by T Subramani, D.Ponnuvel in June 2012. These papers presents the stress analysis of gravity dams is performed to determine the magnitude and distribution of stresses throughout the structure for static and dynamic load conditions and to investigate the structural adequacy of the substructure and foundation. The STAAD Pro provides the most appropriate values to learn or investigate a constructed dam or pre constructed dam. He tells that the computations are very difficult to perform, due to coupling between the uplift pressure and the cracking length.



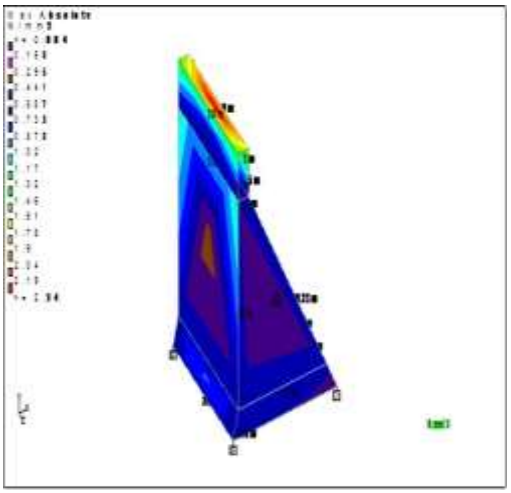
by T subramani



by T Subramani

3 “Stability Analysis of Concrete Gravity Dam for Seismic Loading in Afghanistan” by Mohammad Ejaz Shahir, Priyanka Dhurvey in June 2017. The results of 2D analysis are found very close to 3D results for Kabul but for Herat the maximum stresses obtained from ANSYS vary significantly from the stresses obtained using analytical 2D gravity method because the minimum stress at toe , was found negative in 2D Gravity method. In terms of seismic static stability (especially in crushing)the 2D and 3D analysis giving safe results for both the cases as their stresses values are less than 3 MPa. In this paper finally they concluded that the selected section of the dam is under development of the tension.

4.”Stability Analysis of Gravity Dam by Using STAAD Pro in Time History Method” by S.Sree Sai Swetha in March 2017, STAAD Pro is one of the most widely used structural analysis and design software. It can also make use of various forms of dynamic analysis from modal extraction to time history and response spectrum analysis. These paper presents the stability and shear analysis of the gravity dam with the finite element method analysis.



by S.Sree Sai Swetha

5 “Seismic & Stability Analysis of Gravity Dam” by Miss. Meghna S. Bhalodkar in 2014
In this paper, the stability analysis of the dam but not considered the seismic analysis of the dam. The stability analyzed by calculating the moments, frictional force, shear friction force. It is observed that value of vertical forces remained unchanged but seismic forces increases value of horizontal forces which resulted in instability against sliding.

6 “Analysis of Concrete Gravity Dam by 3D Solid Element Modeling using STAAD Pro” by Jay p. Patel, R. Chhaya in May 2015
In this paper, the 3D modeling and analysis of gravity dam of solid elements using STAAD pro. The loads and the load combinations are

consider as per 6512. In this paper, directly analyzed the dam by solid elements using STAAD Pro. There are some uncertainties still prevailing regarding stability at support conditions. In this paper, Solid foundations are consider to avoid this situation.

7 "Design and Analysis of Gravity Dam –A Case Study Analysis Using STAAD-Pro" by mettu Rajesh Reddy, M.Nageswara rao in 2017
In this paper, the dam body is modeled in STAAD.pro using the SOLID isoperimetric finite elements with eight nodes. Each node has three translational degrees of freedom. The stiffness matrix of the solid element is evaluated by numerical integration with eight Gauss – Legendre points. Analyzed for several basic loads and load combinations possibly met with during its service.

8. "Finite Element Analysis of Concrete Gravity Dam by Using STAAD-PRO" by Rampure Aarti Baburao, Mangulkar Madhuri in 2016
In this paper, the present study undertaken deals with time history method of dynamic analysis. Time history is available only for X direction, so in order to apply forces in different angles, the structure has to be rotated with incidence angle from 0 to 90 degrees, with an increment of 10 degrees and column forces have been investigated in all cases. The base of the dam is to rest on rock and the extra excavation is to be fill with concrete of same strength, the foundation rock of approximately equal to the height of dam is model around and below the foundation level.

Sl.no	Author	Description	Result
1	Jay P. Patel Prof. Zalakkumar R. Chhaya in 2015	The 3D modeling of the concrete gravity dam of STAAD Pro. The loads combinations are considered as per IS 6512. With two conditions i.e. with the opening and without opening of drainage gallery	At finally the stress values are described. The maximum stress, with opening is 4193.257 KN/m^2 and without opening is 3117.744 KN/m^2
2	Miss. Meghna S.Bhalodkar 2014	The stability analysis of RCC dam is done with the trapezoidal structured dam in both presents and absents of seismic force.	The stability analysis of gravity dam with over turning, sliding and shear force is stable. After considering the seismic force the overturning and sliding force are

			instable and shear friction is stable in both conditions.
3	S.Sree Sai Swetha 2017	The examination is done between the identical static methodologies of seismic investigation with element examination by utilizing time history method.	Moment in z-direction is more at zero degrees for both L shape and T shape. Finally reviewed that T shape structure needs to oppose the more stress than the L shape structure.
4	mettu Rajesh Reddy, M.Nages wara rao in 2017	The objective of the paper is to have the direction of the stability analysis of dam with considering the solid elements using STAAD. Pro	After the analysis of the dam, the deflection is very less which is negligible. STAAD Pro gave the optimized practically to implement the structure.
5	Ren Xuhua, Shu Jiaqing, Ben Nenghui, Ren Hongyun in 2008	The anti-sliding stability analysis of concrete gravity dam with the week structural planes and deformation of the material.	In this paper the strength reserve coefficient method with the partial with partial safety factors is essentially based on the reliability method, which demonstrates that the method is effective in the stability analysis and safety evaluation of a gravity dam with multiple slide planes
6	Mathieu Rochon-Cyr, Pierre Léger In 2009	In this paper the shear stress and shake table sliding test are performed to the 1.5mts height of concrete gravity dam	The uses of sinusoidal pulse and earthquake ground motions are shown that residual sliding is larger for the

		model. The shear test is performed with the sliding crakes in dry, wet and in maximum uplift water pressure conditions.	low frequency content signal (2 Hz) than for the high frequency content signal (10 Hz). The uplift pressures reduce the resultant vertical force, promoting sliding displacements
7	Md.Hazrat Ali, Md.Rabiul Alam in 2011	This paper deals with time history method of dynamic analysisand how it is used in application in a designing gravity dam	The main discussion is to reduce sliding and to reduce silt pressure and technics of construction joints to improve the factor of safety

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. 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.

Reference:

1 "Seismic and Stability Analysis of Gravity Dams Using Staad PRO" by T Subramani, D.Ponnuvel. in June 2012

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7 "Finite Element Analysis of Concrete Gravity Dam by Using STAAD-PRO" by Rampure Aarti Baburao, Mangulkar Madhuri in 2016

8 Structural Stability And 2D Finite Element Analysis of Concrete Gravity Dam by Khalid Dawlatzai, Dr. Manju Dominic

9 Stability analysis of concrete gravity dam on complicated foundation with multiple slide planes by Ren Xuhua, Shu Jiaqing, Ben Nenghui, Ren Hongyun in 2008.

10 Seismic cracking analysis of concrete gravity dams with initial cracks using the extended finite element method by Sherong Zhang, Gaohui Wang, Xiangrong Yu in 2013

11 "Comparison of Design and Analysis of Concrete Gravity Dam"by Md. Hazrat Ali, Md. Rabiul Alam in 2011

12 Shake table sliding response of a gravity dam model including water uplift pressure by Mathieu Rochon-Cyr, Pierre Léger in 2009

13 Shake table sliding response of a gravity dam model including water uplift pressure by Mathieu Rochon Cyr, Pierre Léger in 2013

14 Seismic fracture analysis of concrete gravity dams including dam–reservoir interaction by Yusuf Calayir, Muhammet Karaton in 2005

15 Seismic structural stability of concrete gravity dams considering transient uplift pressures in cracks by Farrokh Javanmardi, Pierre Léger, René Tinawi in 2004.