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# Comprehensive Analysis of Dam Structures Under Hydrostatic Pressure Using STAAD.Pro

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**Abstract -** *This study explores the stress distribution in gravity dams, emphasizing the role of self-weight. Two 3D models of a gravity dam with identical geometry were analyzed using STAAD.Pro V8i SS5. One model considered only hydrostatic pressure, while the other included the self-weight of the dam. Finite Element Analysis (FEA) was performed to compute bending (MXY), membrane (SXY), and shear stresses (SQX, SQY), offering insights into internal forces within the structure.*

*The analysis identified critical areas of stress concentration and highlighted the influence of self-weight on overall stress patterns. By examining key stress parameters, this study underscores the importance of considering self-weight in gravity dam design to ensure structural integrity.*

***Key Words***: Gravity dams, hydrostatic pressure, self-weight, shear stress, bending stress, structural analysis, STAAD.Pro.

## 1.INTRODUCTION

Massive monolithic structures known as gravity dams use gravity's unstoppable force to withstand the tremendous pressures that impounded water exerts. The material known for its compressive strength, concrete, is usually used to build these enormous engineering feats. Their design is based on a simple but profound fundamental principle: the massive weight of the dam counteracts the horizontal thrust generated by the water body, ensuring stability and averting catastrophic failure. The precise calculation and optimization of this weight-water pressure equilibrium ensures the structural integrity of the dam for the duration of its intended life.

Although the idea behind gravity dams may seem straightforward, designing and building them requires a thorough understanding of soil mechanics, hydrodynamics, structural engineering, and materials science. The dam's dimensions, shape, and material composition are greatly influenced by a multitude of factors, including the hydrological conditions, seismic activity, geology of the site, and environmental considerations. It is crucial to analyze the stresses in these structures to guarantee their durability and safety. Preventing structural failures requires an understanding of the distribution of forces, especially those caused by the weight of the dam and water pressure. This study explores the complexities of stress analysis in gravity dams by simulating and assessing the behavior of these enormous structures under a range of loading scenarios using sophisticated computational tools. Through the comparison of stress patterns in dam models under varying load combinations, our goals are to clarify the influence of self-weight on the overall stress distribution, pinpoint critical stress areas, and further advance the continuous improvement of principle of gravity dams. To guarantee the stability and safety of gravity dams over the long term, a thorough understanding of the stress distributions inside the structures is necessary. Through the application of diverse loading scenarios to these structures, engineers are able to determine the critical stress zones and evaluate the design adequacy of the dam.

This study performs complex finite element analyses using the sophisticated capabilities of STAAD.Pro V8i SS5, yielding a precise and comprehensive representation of stress patterns. This study attempts to quantify the impact of gravity on the overall stress field by comparing dam models with and without self-weight considerations, thereby aiding in the development of more resilient and effective dam designs.

## 2. TYPE OF ANALYSIS

### Stress analysis

A crucial area of engineering called stress analysis studies the internal forces and deformations that occur in a structure or component when it is subjected to external loads. It is necessary to guarantee the dependability and safety of structures. Engineers analyze the distribution of stress, pinpoint high-stress areas, and forecast probable failure points using computational tools and mathematical models. In order to determine stress and strain values, the procedure usually entails defining the geometry of the structure, applying loads and boundary conditions, choosing suitable material properties, and solving the governing equations. Engineers can prevent structural failures, optimize designs, and use less material by using stress analysis.

### Dynamic analysis

The behavior of structures under time-varying loads, such as vibrations, shocks, or earthquakes, is the focus of dynamic analysis. It entails forecasting a structure's motion, stresses, and deformations by analyzing how it reacts to dynamic excitations. For structures like machinery, buildings, and bridges, where dynamic loads can have a major 9

impact on performance and safety, dynamic analysis is essential. A popular method in dynamic analysis for figuring out a structure's natural frequencies and mode shapes is modal analysis. In order to prevent excessive vibrations, these parameters help identify possible resonance conditions and guide design modifications. An additional technique for examining how a structure reacts to particular time-varying loads, like ground motions from an earthquake, is time-history analysis.

### Finite element analysis

A numerical technique for approximating solutions to engineering problems involving fluid flow, heat transfer, stress, strain, and other physical phenomena is called finite element analysis (FEA). It entails breaking down a complicated structure into smaller, more manageable components known as finite elements. The behavior of each element is represented by mathematical equations, and these elements are connected at nodes. FEA is widely used because of its accuracy and versatility in a wide range of engineering fields. It enables engineers to study intricate geometries, model real-world conditions, and forecast how structures will respond to various loading scenarios. Static, dynamic, and nonlinear problems can all benefit from the use of FEA, which offers insightful information for troubleshooting and design optimization. To provide comprehensive information about stress distributions, displacements, and other pertinent parameters, FEA is frequently used in conjunction with dynamic analysis and stress analysis.

## OBJECTIVE OF THE RESEARCH

The main objective of the research are-

- To design and analyse the structure of gravity dam using STAAD.Pro software.
- To check the performance and effect of gravity dams.
- To analyze causes of failure of structure of dams.
- To compare two structure of dams on the basis of several parameters such as shear, bending etc.

## 3. METHODOLOGY

In this chapter we are representing design and methodology possess of gravity dams where all the steps from model preparation to analysis of the model is shown in this portion, here two dam structure are considered where first dam is designed under gravity loading and the other is designed without gravity loading.

Steps involved in modeling and design of gravity dam

**Step 1:** Model preparation of gravity dam.

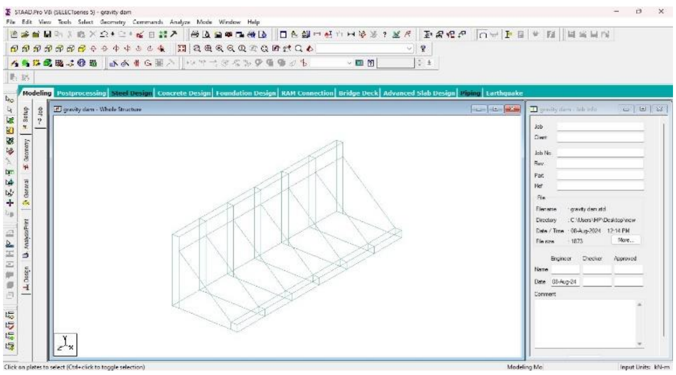

*Fig 3.1 Model Preparation*

Step 2: Assigning fixed support at the bottom of the structure of the dam.

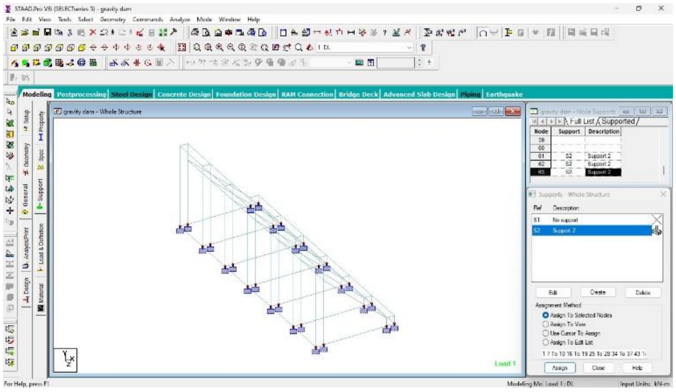

*Fig 3.2 Assignment of fixed supports*

Step 3: Assignment of element thickness with property of material.

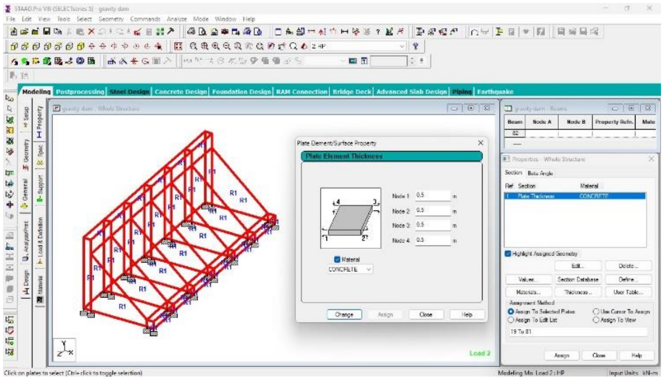

*Fig 3.3 Assignment of plate thickness*

Step 4: defining loading such as self-weight and hydraulic pressure.

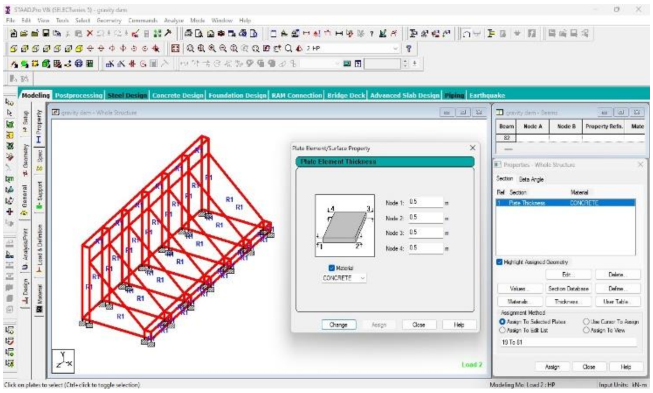

*Fig 3.4 Assigning self-weight*

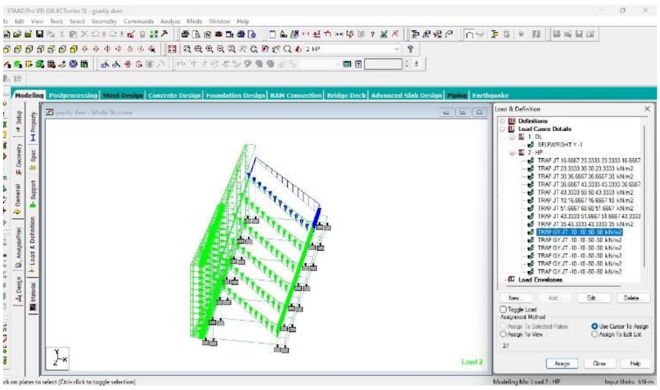

*Fig 3.5 Hydraulic pressure*

Step 5: Assignment of design parameters

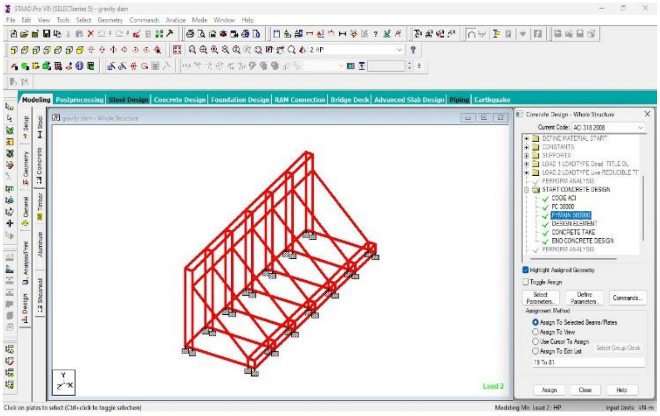

*Fig 3.6 Assigning design parameters*

Step 6: Analyzing the structure for dead loading, displacement

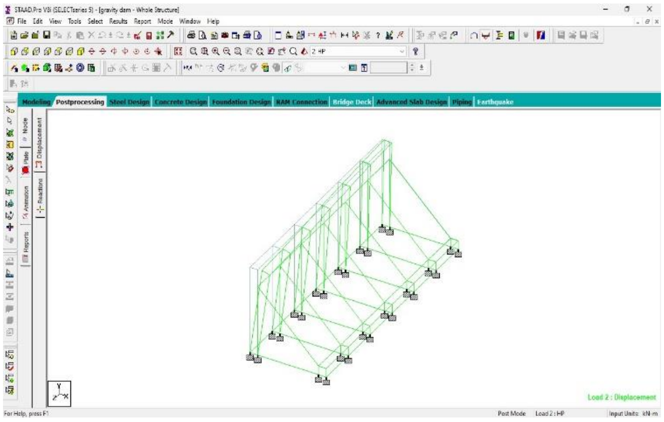

*Fig 3.7 Displacement*

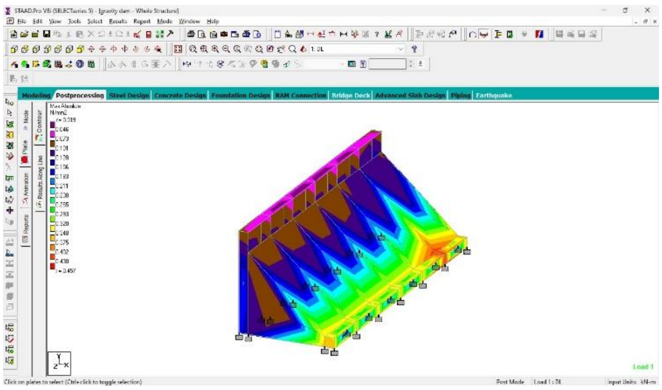

*Fig 3.8 Stress analysis*

## 4. Geometrical specifications and Properties

*Table 4.1 Geometric Data*

| | |
|---|---|
| Type of the dam | Gravity dam |
| Height of the dam | 10m |
| Length of the dam | 30m |
| Width of the dam | 10m |
| width of the spillway | 5m |
| Length of the spillway | 10.63m |
| Thickness of the base plate | 500mm |

*Table 4.2 Properties of Concrete*

| | |
|---|---|
| Grade of Concrete | M-25 |
| Directional Symmetry Type | Isotropic |
| Weight per Unit Volume | 25kn/m3 |
| Modulus of Elasticity, E | 25000n/mm$^2$ |
| Poisson's Ratio, U | 0.25 |
| Coefficient of Thermal Expansion, A | 12×10−6/°C |
| Shear Modulus, G | 10 GPA |

*Table 4.3 Property of Rebar*

| | |
|---|---|
| Material Name | HYSD 500 |
| Directional Symmetry Type | Uniaxial |
| Weight per Unit Volume | 76.9729 kN/m3 |
| Mass per Unit Volume | 7849.047 kg/m3 |
| Modulus of Elasticity, E | 200000 MPa |
| Coefficient of Thermal Expansion, A | 0.0000117 1/C |

## 5. Result Analysis

In this section, observed results from the comparison of both cases for dam structures are shown in tabular and graphical form, where the dam that is designed under gravity loading is shown with a higher value of each parameter that we have considered for the comparison. For the comparison, we have considered two cases of dam structures, where the first structure is designed using gravity loading and the other is designed without gravity loading.

### 5.1 Bending MXY

Table 5.1 Bending MXY in N/mm2

| with gravity loading | without gravity loading |
|---|---|
| 62.684 | 3.006 |

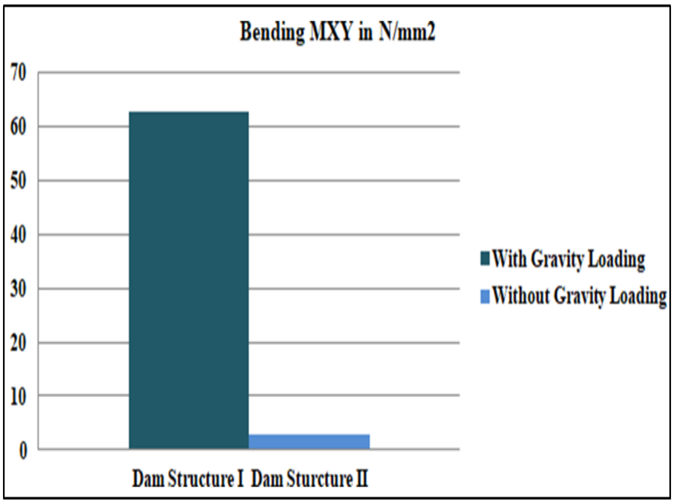


Figure 5.1 Bending MXY in N/mm2

It is clear that the bending MXY is observed higher in that model which is designed using gravity loading and this value is approximately 95% higher to other model which is designed without gravity loading.

### 5.2 Shear SQX

Table 5.2 Shear SQX in N/mm$^2$

| with gravity loading | without gravity loading |
|---|---|
| 0.333 | 0.012 |

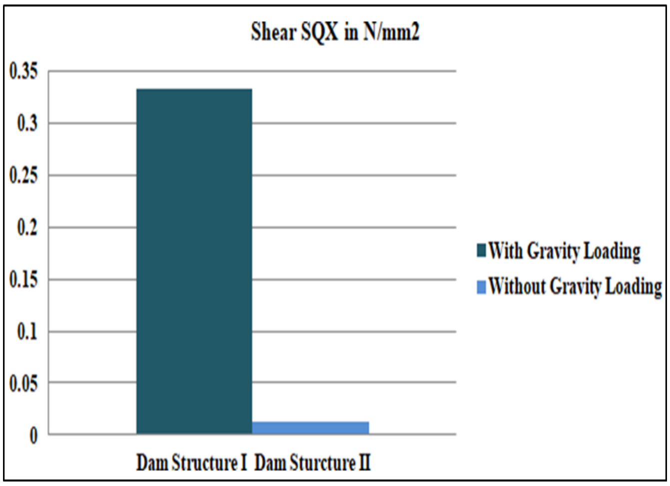


Figure 5.2 Shear SQX in N/mm$^2$

It is clear from observation that the value of shear SQX for 1st model which is designed under gravity loading is found approx. 96% higher as compared to other model of dam.

### 5.3 Shear SQY

Table 5.3 Shear SQY in N/mm2

| with gravity loading | without gravity loading |
|---|---|
| 0.689 | 0.029 |

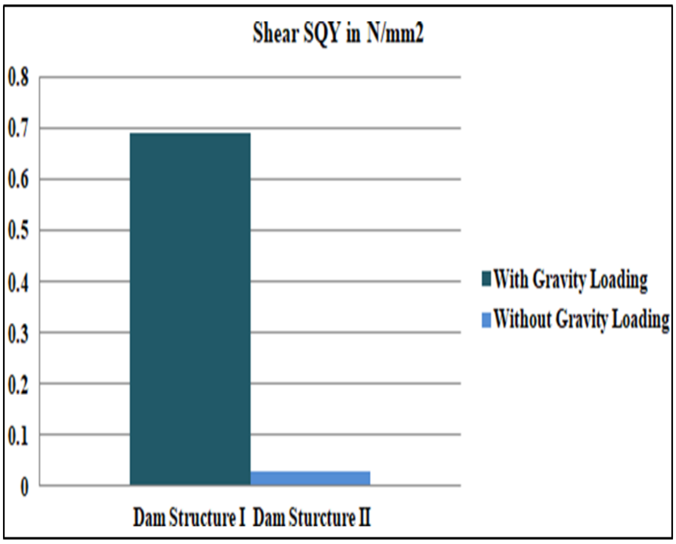


Figure 5.3 Shear SQY in N/mm2

it was observed that the shear SQY value is observed higher in case 1 which is designed under gravity loading and it is higher by 96% from other model of dam.

### 5.4 Membrane SXY Membrane SXY

Table 5.4 Membrane SXY Membrane SXY in kNm/m

| With Gravity Loading | Without Gravity Loading |
|---|---|
| 0.698 | 0.074 |

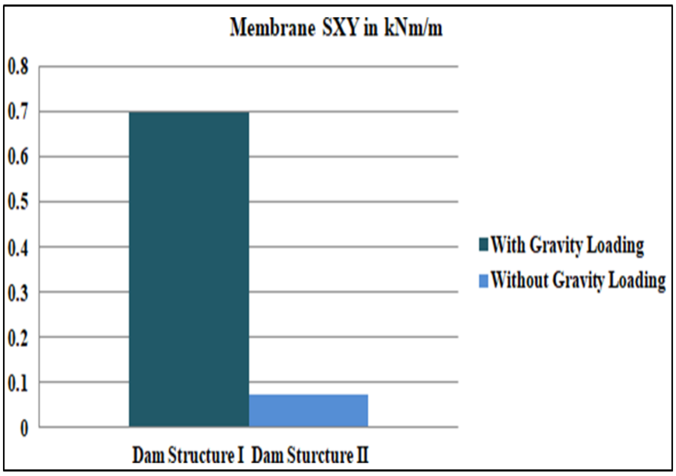


Figure 5.4 Membrane SXY Membrane SXY in kNm/m

The models proved that the model which is designed under gravity loading, shows higher value as compared to other model of dam and it is higher by approx 89% as compared to that model which is designed without gravity loading.

## 6. CONCLUSION

**Bending Moment (MXY):** The bending moment MXY for the first structural model of the dam, designed with gravity loading, is approximately 63 N/mm², whereas the second model, designed without gravity loading, has a value of approximately 3 N/mm². This indicates that the bending MXY is significantly higher (about 95%) in the model with gravity loading.

**Shear Stress (SQX):** For the first dam model designed under gravity loading, the shear stress SQX is approximately 0.333 N/mm². In contrast, for the second model without gravity loading, the shear stress is approximately 0.012 N/mm². The value of SQX for the gravity-loaded model is about 96% higher than the one without gravity loading.

**Shear Stress (SQY):** The shear stress SQY for the gravity-loaded dam model is approximately 0.689 N/mm², while for the model without gravity loading, it is around 0.029 N/mm². This demonstrates that SQY is about 96% higher in the gravity-loaded model.

**Membrane Stress (SXY):** The membrane stress SXY for the first dam structure, designed under gravity loading, is approximately 0.698 kNm/m. In comparison, the value for the second dam structure, without gravity loading, is about 0.074 kNm/m. This shows an 89% higher value of SXY in the gravity-loaded model.

## 7. Future Scope of the Research

This research opens several avenues for future studies, including:

- Comparing the performance of gravity dams with other dam types under similar conditions.
- Incorporating wind and seismic loading into the analysis of gravity dam structures.
- Conducting time history analysis to evaluate the safety and performance of gravity dams under dynamic loading conditions.

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