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Construction and Seismic Performance Evaluation of Concrete Water Tanks

Koushal Dhamija[1], *OSD* Hima Bindu[2], *N V* Uma Reddy[3*], *Rajeev* Sobti[4], *Q*. Mohammad[5], *Ravi* Kalra[6], *B Nagaraj* Goud[7]

[1]Lloyd Institute of Management and Technology, Greater Noida, Uttar Pradesh, India.
[2]Department of Civil, GRIET, Bachupally, Hyderabad, Telangana, India.
[3]Department of Artificial Intelligence and Machine Learning, New Horizon College of Engineering, Bangalore, India
[4]Lovely Professional University, Phagwara, India
[5]Hilla University College, Babylon, Iraq
[6]Lloyd Institute of Engineering & Technology, Greater Noida, Uttar Pradesh, India.
[7]Department of Aeronautical Engineering, MLR Institute of Technology, Hyderabad, Telangana, India-500094

Abstract- The construction of concrete water tanks is a crucial aspect of water distribution structures, ensuring dependable water supply at predetermined elevations for numerous purposes. Municipalities and corporations closely depend upon these tanks to store water, combustible fluids, and synthetic compounds. However, the safety of these tanks, especially during seismic events, is paramount. To address this, robust support structures inclusive of reinforced concrete (RC) propped outlines, metallic frameworks, RC shafts, and masonry platforms are employed. The RC casing approach could be the most common support system due to its effectiveness and durability. This paper gives a FEM based technique the use of Staad.pro employed inside the construction and evaluation of concrete water tanks.

Keyword-: Water tank, FEM, Stad.pro, concrete, support systems

1 Introduction

A raised water tank serves as a vital factor in water distribution systems, presenting a reliable supply of water at a predetermined elevation. Those tanks are important for ensuring adequate water stress and availability for numerous purposes. Municipalities and companies depend on fluid garage tanks not only for water but additionally for storing flamable fluids and synthetic compounds. But, it is critical to note that tanks containing unsafe or flammable substances pose widespread protection concerns, particularly for the duration of seismic events. To mitigate risks, these tanks are prepared with strong help structures, together with bolstered concrete (RC) propped outlines, metal frameworks, RC shafts, and masonry structures [1]. Every assist machine is designed to resist the load of the tank and its contents

* Corresponding Author: nvumareddy@gmail.com

at the same time as maintaining structural integrity, even under seismic pressure. Amongst these help systems, the RC casing approach is the maximum commonly followed due to its validated effectiveness and sturdiness, as shown in Fig.1. In the course of seismic events, making sure the integrity of fluid garage tanks is paramount to prevent leakage or spillage of risky materials. Proper layout and production techniques, along with everyday preservation and inspection, are essential for boosting the resilience of those tanks in opposition to seismic forces. By way of enforcing suitable aid systems and adhering to protection protocols, the risk of loss or damage to tank contents may be minimized, safeguarding each human life and the environment [2].

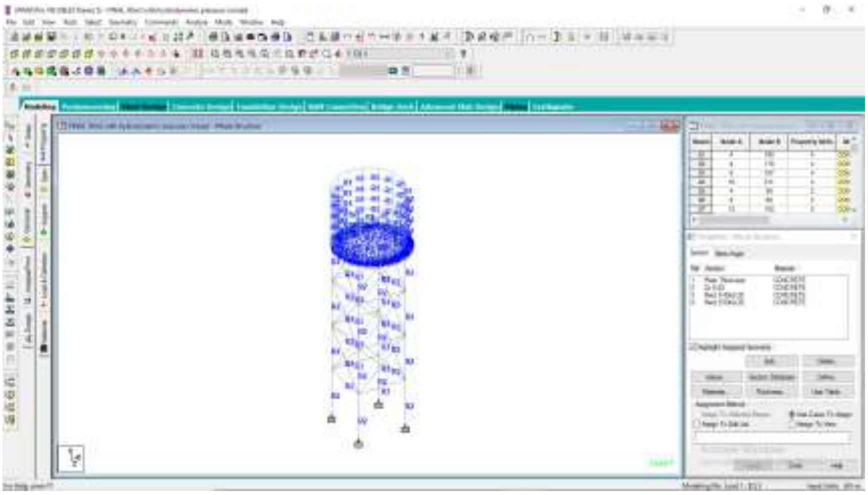

Fig. 1: Elevated Water Tank Supported by Inclined Columns

Component of factories, fireplace structures, and civic water structures is the raised water tank. Damage from earthquakes can threaten the provision of easy drinking water, positioned out fires, and result in financial loss. It is vital to investigate the seismic behavior of these buildings so one can fulfil safety requirements and shop constructing and maintenance charges. Using ANSYS software program, the study examined the response behavior of a raised RCC rectangular water reservoir under numerous water fill situations. The reactions of the tanks expanded with water height, according to the consequences [3]. Although concrete water tanks need to meet stringent requirements for serviceability, severe fractures can compromise their integrity and result in leaks. A 30 x 20 x 3.6 m water tank near the Arabian Gulf has cracks, according to a discipline exam [4-7]. To decide the problem and placed a restore plan into conduct, diagnostics research, outdoor inspections, lab testing, and 3-d modeling have been carried out. The study examined the properties of the concrete mix's heat of hydration using a semi-adiabatic calorimeter. It turned into discovered that tank walls cracked because of tensile loads which have been too amazing due to shrinkage lines and temperature. To get functionality backwards, a repair plan was counseled [8]. The use of non-corrosive reinforcing in reinforced concrete tanks of water and wastewater treatment centers is investigated in this study. It compares four substances—glass-fiber strengthened polymer (GFRP), stainless steel, epoxy-covered steel, and black iron—using existence-cycle cost evaluation [9]. The findings display that, despite its high preliminary cost, GFRP begins getting inexpensive following 35 years, suggesting that it is able to be a viable alternative for lengthy-time period concrete durability. In step with the have a look at, the internet cutting-edge cost of GFRP-strengthened concrete become 43% much less than that of black metal-bolstered concrete. Stainless steel was much less economical but had a twenty-five percent decrease NPC. Epoxy coated metal confirmed a 15-12 months' growth in lifespan and an 11% discount in NPC [10-13]. The study discusses the design processes, building specifics, leakage testing, and monitoring outcomes for the world's first reinforced-concrete water chlorination tank. The purpose of the tank is to solve corrosion issues in RC tanks triggered by particular substances or treatment techniques' tank for a new water treatment facility is being built in Thetford Mines, Quebec, Canada. With a capacity of more than 2,500 m3, the tank satisfies the serviceability and durability specifications of ACI 350/350R-06, CAN/CSA S806-12, and ACI 440.1R-06. It is reinforced with GFRP bars [14]. Using non-destructive testing, this research assesses the state of brought up cement water tanks, including the development of cracks. Requirements for environmental quality influence tank design and construction. Water line cracks can pollute groundwater and harm storage tanks [15]. The research looks at leaks' causes and consequences. In addition to visual evaluations, hammer checks, design checks, cement compression tests, and Ultrasonic Pulse Velocity testing on tank construction parts was also part of the inquiry. Results included higher bending that planned, over time drying shrinkage cracks on the diagonally of the floor foundation, and flex type fractures in the centered span and diagonally beams of the main beam [16]. The behaviour of an elevated concrete water tank under seismic stress is investigated in this work by means of artificial seismic stimulation. It contrasts seven instances using models from the finite element strategy, mechanical designs, and actual dynamic analysis. Findings indicate that the axial power, overturning moment, or shear force at the tank's base are significantly impacted [17-20]. For big water tanks used in water treatment plants, in specific, the study revisits the application of iron cement in the construction of civil engineering. It is an appealing substitute that is particularly appropriate for poor nations, despite its low cost and plastic potential. Improving design methods and material comprehension is the goal of current study [21]. At order to compare different finite element models with experimental data, this study looks at numerical and experimental tests on big fibrocement tanks at Indianapolis, Brazil. The focus is on modeling accuracy and homogeneity procedures [22].

One world is becoming more aware of the problems associated with construction and civil engineering systems, especially as they relate to building water tanks. For the sake of economy, sustainability, as well as quality control, hybrid fiber concrete is the main focus of concrete manufacturing. Using this method will improve the quality of the finished product whereas building water reservoirs in Malaysian [23]. This study examines the nonlinear seismic response of raised water tanks made of reinforced concrete (RC), with an emphasis on a variety of tank sizes and RC pedestal measurements. Then takes a methodical approach, choosing and creating 48 model configurations, and then does linear static analysis utilizing a finite element technique. Research is being done to establish seismic reaction parameters for raised water tanks and to produce pushover curves for models [24]. The characteristics that are evaluated include the seismic design category, tank size, height to diameter ratio, and basic frequency. It shows that two cracking patterns are seen and that the size of the tank is important in seismic reaction [25]. The study investigates the application of water tanks as passively adjusted liquid dampers to reduce seismic activity in reinforced concrete structures. Tests were conducted on three 4-story models using a shaking table with different water levels. According to the study, for Models 1 and 2, water masses of 3.5 and two percent, respectively, provided the least reaction velocity and deflection [26-30]. In this essay, precast concrete water tanks and the R.C. water tanks are contrasted. It creates R.C.C. water tanks with an average size and uses MS Excel programming to compare the outcomes. RCC water tanks are more affordable for smaller-diameter tanks, but not for bigger ones, according to the results. The study highlights how crucial it is to choose the appropriate construction method for certain situations and building types [31]. Utilizing a probabilistic approach grounded on FAME P695, a research verifies the response modification factor of reinforced concrete pedestals in raised water tanks. Using incremental dynamic analysis, the likelihood of collapse under various seismic loading situations is calculated for ten models that have different tank abilities and pedestal elevations. The nature of linear earthquakes is shown to be greatly influenced by tank size, with larger, heavier tanks being more susceptible [32-34]. Following sixty years of functioning, the highest possible and serviceability limit states for a reinforced concrete water towers tank are examined in this research. It consists of experimental research, site surveys, and computations to evaluate the load-bearing capacity, crack widths, and technical state of the tank and suggest structural repairs [35].

2 Problem Identification and Loading condition

This study aimed to evaluate the seismic performance of RCC elevated water tanks with columns positioned at various slant degrees. Loading conditions, including dead weight, seismic load, and hydrodynamic load under full water conditions, were considered. Altering the placement of columns can mitigate tensional modal analysis in circular tanks. Despite circular tanks being more cost-effective, rectangular tanks require a larger number of nodes for structural modelling. Structural modelling and analysis were conducted using the analytical software STAAD.Pro.

Concrete utilized in construction is of M30 grade, while reinforcement bars are of FE500 quality. The modulus of elasticity is measured at 1.95 x 10^5 Mega Pascals (MPa), with an ultimate tensile strength of 1860 MPa. The soil type is categorized as medium, while wind pressure is recorded at 39 meters per second. Hydraulic pressure considerations encompass tension and stress factors. Finally, seismic loads are accounted for within Zone II parameters. Those material residences serve as foundational facts crucial for design and construction levels, ensuring structural integrity and protection requirements are met.

The geometrical facts for the tank consists of a peak of 3.5 meters and a staging top of 8 meters. The tank's base diameter measures 4.4 meters, matching the diameter of the field. Supported by four columns, the tank is constructed the use of M30 grade concrete and reinforced with FE415 grade steel. Each column has a length of 500 square millimetres, even as beams degree 350 through 250 millimetres. Plate thickness is about at 800 millimetres, with wall thickness at 450 millimetres. For added support, bracing is furnished through I.S.M.B. 100 individuals. These specs offer important facts for the layout and construction stages, ensuring structural integrity and adherence to safety standards throughout the challenge.

3 Proposed Methodology

Study results were evaluated in many steps in order to ensure comprehensiveness and accuracy. A literature review was conducted as the first step to gather pertinent data and insight from previous studies regarding the underlying case. To comprehend the context and background of the study, existing literature, studies, and reviews were reviewed. Based on the results of this investigation, upcoming research and investigation are needed to address limitations or gaps in current studies. Analytical software STAAD.pro was used to prepare a geometrical shape for the study. The word STAAD refers to Structural Analysis and Design. One well-known program for assessing and developing structures, including buildings, towers, highways, industrial use, modes of transport, and functionality structures, is called STAAD Pro. These models were used to create digital versions of the water tank, columns, beams, and other structural elements. The superior features and competencies of STAAD.pro were leveraged to ensure realistic and reliable results. In the third step, the model's structural sections were given material properties. There were specifics that were provided in regard to the concrete, metals, and any other materials that were to be used in the construction, as well as their properties. STAAD.pro will be able to simulate and analyze the structural behavior of the model appropriately after accurately defining the material properties, such as power and elasticity.

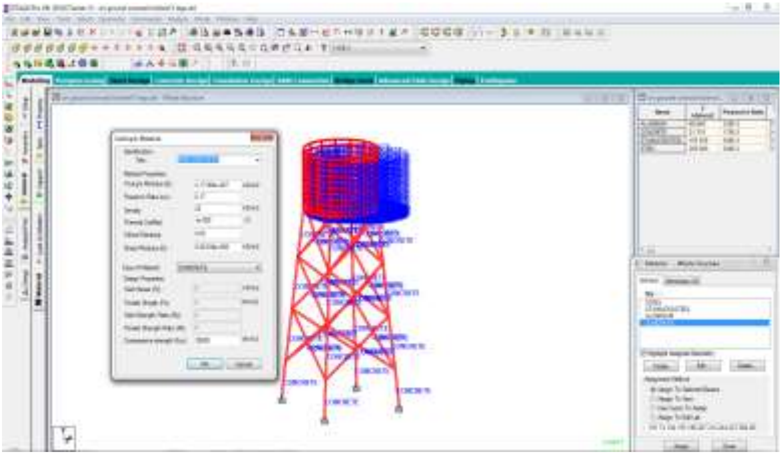

Fig. 2: Assigning Material Properties

As part of step 4, section properties were defined for the structural factors in the model, including geometric characteristics and mechanical characteristics. This step covered specifying the cross-sectional dimensions, including width, intensity, and thickness, of beams, columns, and other structural participants. Moreover, material properties such as modulus of elasticity, yield electricity, and remaining strength had been assigned to appropriately represent the behaviour of the materials underneath load. Through meticulously defining these phase homes, the structural response of the model to diverse loading situations will be accurately expected. This step performed a vital position in making sure the constancy and accuracy of the structural evaluation carried out the use of analytical software program like STAAD.pro.

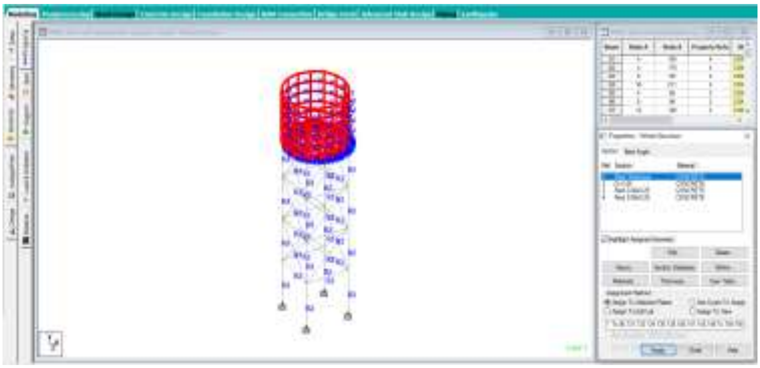

Fig. 3: Sectional Data

Step 5: in this step, weak springs were assigned at the base beams and cylindrical surface of the shape. Susceptible springs, additionally referred to as boundary springs, are virtual elements used to represent the relationship between the shape and its basis or assist machine. By means of assigning weak springs at strategic locations, which includes the bottom beams and cylindrical surface, the interaction between the structure and its surroundings could be appropriately modeled. Those vulnerable springs mimic the flexibility and resilience of the foundation, allowing for a extra realistic simulation of the structural reaction to external loads, which include seismic forces. This step is crucial for capturing the dynamic behavior of the shape and ensuring that the analysis consequences replicate real-world situations appropriately**.**

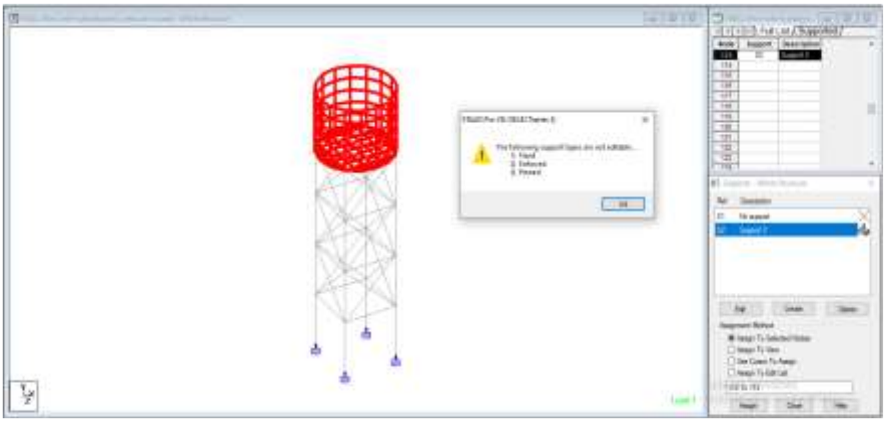

Fig. 4: Assigning Surface

Step 6: Assigning hydrostatic pressure in complete circumstance includes accounting for the strain exerted by way of water when the tank is at full capability. This step is important for as it should be simulating the structural reaction of the tank underneath hydrostatic loading conditions. By way of assigning hydrostatic pressure to the model, the distribution of forces appearing at the tank's walls and base may be appropriately represented. This consists of considering the weight of the water as well as any extra strain exerted because of the intensity of the water column.

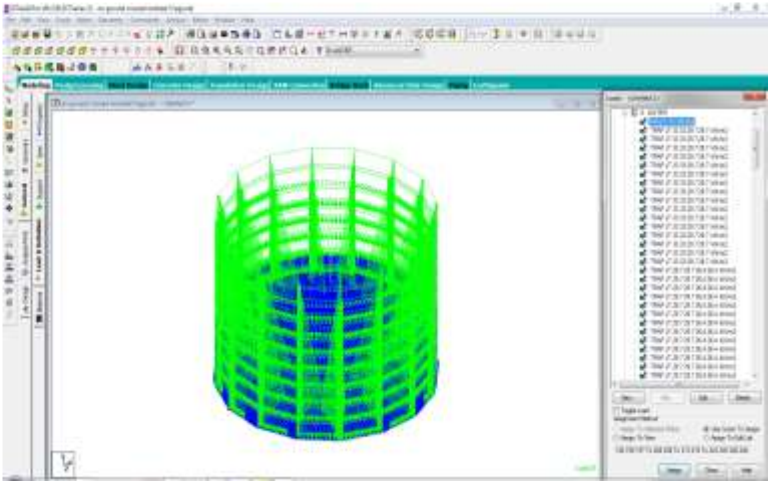

Fig. 5: Assigning Hydrostatic Load

Step 7: Assigning wind pressure as consistent with IS 875-III: 2015, with a wind velocity of 39 m/s, and seismic load as according to IS 1893-I: 2016, involves incorporating external environmental elements into the structural analysis. Wind pressure, according with the relevant code, is applied to the model to simulate the results of wind loading on the shape.

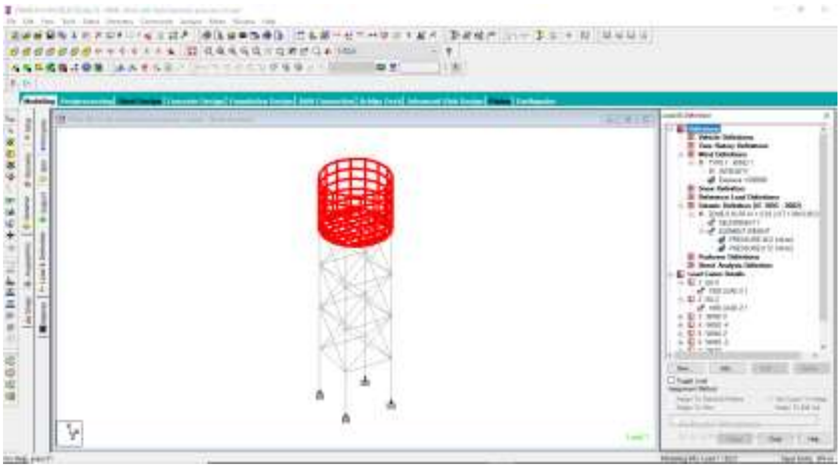

Fig. 6: Assigning Lateral Loads namely wind load and seismic load

Step 8: The Finite element method (FEM) analysis of the structure the use of the analytical application STAAD.pro includes accomplishing a comprehensive computational evaluation to assess the structural conduct and response below numerous loading situations. STAAD.pro utilizes superior numerical techniques to discredited the structure into finite elements, taking into consideration the accurate representation of complex geometries and material behaviours.

4 Results and Discussion

After conducting the FEM analysis the usage of STAAD.pro, the effects were evaluated and post-processed the usage of MS Excel. In this phase, the output records from STAAD.pro, consisting of stresses, displacements, and different structural responses, have been imported into Excel for similarly analysis and visualization.

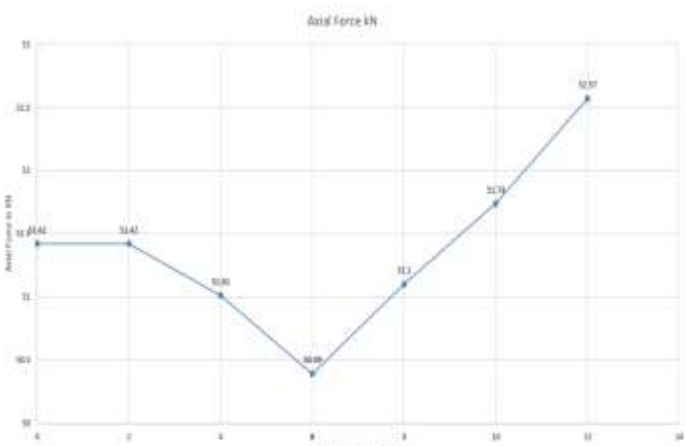

Fig. 7: Axial Force at Top Beam

Fig. 7 indicates the inner force exerted alongside the longitudinal axis of the beam at its uppermost segment. This force can be either compressive (pushing together) or tensile (pulling aside), relying on the loading and structural configuration. Evaluating the axial force facilitates verify the beam's capability to resist vertical loads and contributes to determining its overall structural integrity and stability.

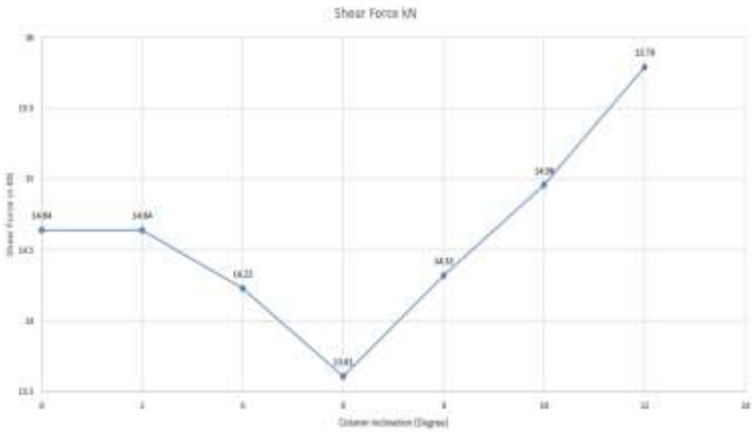

Fig. 8: Shear Force at Top Beam

Fig. 8 suggests the inner force performing parallel to the cross-sectional region of the beam at its uppermost part. This force represents the tendency of one part of the beam to slip or shear beyond another element. Evaluating the shear pressure facilitates determine the beam's resistance to lateral forces and contributes to determining its ordinary structural stability and performance.

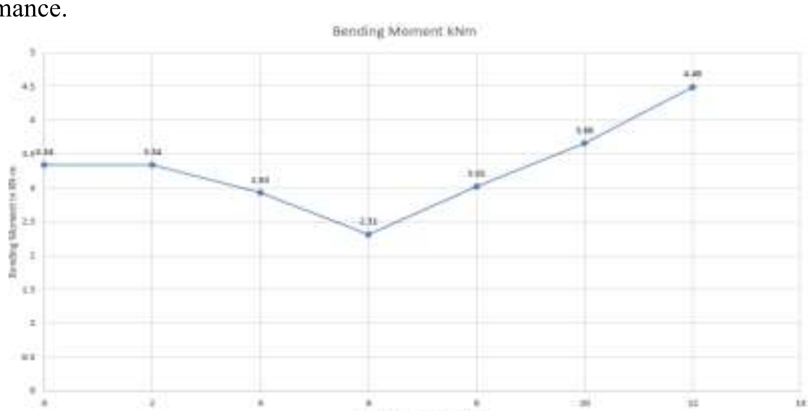

Fig. 9: Bending Moment at Top Beam

Fig. 9 shows the internal second or torque exerted at the beam at its uppermost section because of external loads. This moment induces curvature or bending inside the beam, inflicting it to deflect. Evaluating the bending moment facilitates assess the beam's capacity to resist bending and contributes to determining its usual structural energy and balance.

Fig. 10 shows the force exerted by means of a structural assist, such as a column or foundation, in response to the burden applied to the structure. This reaction pressure acts perpendicular to the help surface and is equal in value and opposite in path to the carried out load. Evaluating help reactions is crucial for studying the structural stability and ensuring that the aid machine can efficaciously bring and distribute the hundreds to the foundation or ground below.

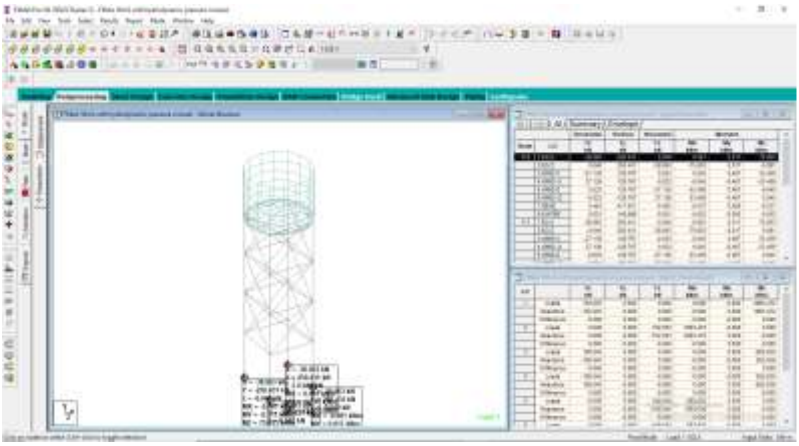

Fig. 10: Support Reaction

5 Conclusion

Concrete water tanks play a essential role in ensuring reliable water supply and storage. By using appropriate support structures and adhering to safety protocols, the risk of harm or leakage all through seismic occasions may be minimized. Numerous studies have explored unique elements of concrete water tank production, along with layout, fabric selection, and seismic overall performance evaluation. These research make contributions treasured insights to the continued efforts to beautify the safety, sturdiness, and efficiency of concrete water tanks. Further studies in this vicinity is important to address emerging challenges and improve the resilience of water garage infrastructure against natural dangers.

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