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Analytical Interpretation of Hydrodynamic Pressure Causing Slosh Effect on Overhead Water Tank

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Abstract: - When a fluid passes and interacts with the tank, the dynamic stress of such an interaction may develop large distortion in the tank wall as well as the supporting structure. Dynamic analysis of a tank holding fluid is a complicated issue involving fluid-structure interaction. The paper outline the response of the supporting structure as well as the rectangular tank boundaries to impulsive and convective pressure that is simulated as a spring mass model. With a dynamic initiation effect such as seismic forces it causes complicated form of inertia forces acting on the fluid and initiates the overflow and sloshing effect subjected to unprotected parts of the tank to massive dynamic loads. The dynamic effects on the supporting structure and the tank walls depends on the filling degree of the tank, is also analyzed. The simulations were carried out to the full tank level by using the STAAD Pro Software.

Index terms- STAAD Pro, Seismic, Impulsive.

I. INTRODUCTION

Storage tanks are major components in water distribution systems, underground fuel storage tanks and liquid storage tanks etc. During earthquakes, due to the seismic stimulations the tank will get vandalized which in turn devastate the life and property. In the case of surface supported tanks earthquake causes heavy sloshingof water resulting in hydrodynamic pressure in the walls of the cistern. In case of failure of the tanks liquid sloshing occurs and cause massive loss of human life and environmental resources. Due to the ejection of noxious components which are stored in the tanks in industries can be the reason of soil contamination and can create unpropitiouseffect in environment., Sloshing, the term refers to the movement of liquid with an irregular pattern in a tank with splashing sound. It is can also bedescribed as there is a periodic movement of the free surface when the cistern or tank is partially filled. In various engineering disciplines sloshing is important such as fluctuation of liquid in a reservoir due to earthquake,in pressure suppression pools of boiling reactors and etc. Dynamics of flow inside the tank is ruined by the liquid sloshing and free surface movement and it also affects the tank itself. The liquids which are stored in tanks have to withstand the tortuous dynamics of the transportation system and for different earth surface movements. This inevitable movement of the tank and the forces allied on the liquid inside results in mostly savage and disordered movement of the liquidinterface or free surface.Various soil conditions are considered in order to design the liquid storage tank and for the analytical study we can use STAAD Pro V8i software.STAAD Pro V8i is used to calculate the lateral stiffness of frame staging.

II. ANALYSIS OF RECTANGULAR WATER TANK FOR IMPULSIVE & CONVECTIVE FORCES USING STAAD-PRO

STAAD or (STAAD.Pro) is a structural analysis and design computer program originally developed by Research Engineers International in Yorba Linda, CA. In late 2005, Research Engineers International was bought by Bentley Systems. STAAD.Pro is a comprehensive and integrated design and finite element analysis tool. The exponential growth of the Indian as well as the global construction industry has directly impacted the demand for structural engineers. It includes state of the art user interface, visualization tools and international design codes. It is used for 3D model generation, analysis and multi-material design.

The commercial version of STAAD.PRO supports several steel, concrete and timber design codes. It is one of software application created to help structural engineers to auto mate their tasks and to remove the tedious and long procedures of the manual methods.

III. METHODOLOGY

After applying the dimensions and required parameters, a geometric structure of a Over head rectangular tank in an isometric view is obtained. The structure can be viewed along any axis i.e., along x-axis, y-axis and z-axis and also in isometric view

Figure 1. Geometric Structure of a rectangular water tank in an isometric view

MESHING

The Geometry is imported for meshing and analyzing. Structured quadrilateral mesh with the following parameters was done on STAAD Pro. The meshing parameters and the mesh view of the Rectangular Tank is shown in figure.

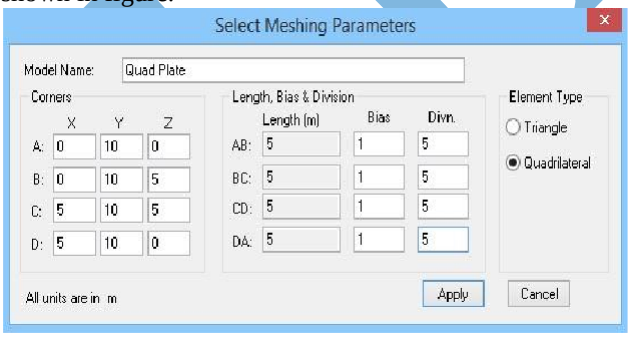

Figure 2. Meshing parameters

SUPPORTS

Fixed supports are applied to the residential building since horizontal movement and rotation are allowed.

The fixed supports as assigned as shown in the figure 3

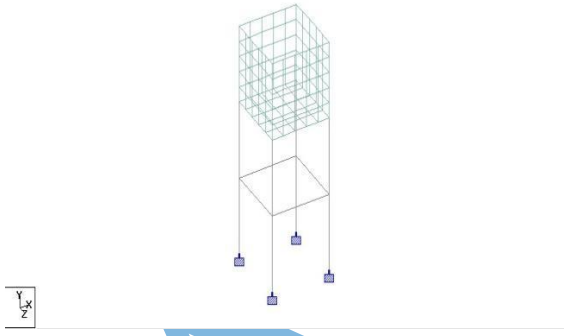

Figure 3. Fixed supports

ASSIGNING PROPERTY

Assigning a property means to provide dimensions such as width, thickness etc. to

- Beams
- Columns
- Plate

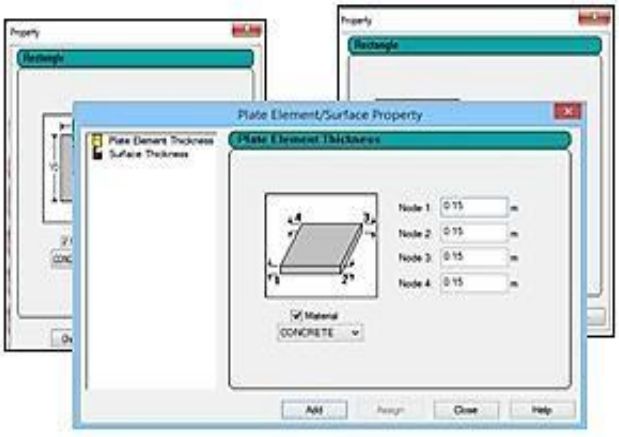

Figure 4. Assigning properties for Beams, coloumns and plate.

The beams and columns dimensions are assigned as 0.30 x 0.25 m and 0.45x0.25 m

The plate element thickness is given as 0.15m.

Impulsive and Convective Pressure Parameters:

The parameters of hydrostatic forces acting on the walls of the tank are depicted as per IS 1893 (Part II) : 2002 code. The working model of elevated water tank which is considered is assumed to be a spring mass model. When there are oscillations or vibrations of the tank which in turn creates pressure inside the tank due to seismic effect we call it as a impulsive pressure. Whereas if the water

itself is excited due to sloshing effect we name it as convective pressure.

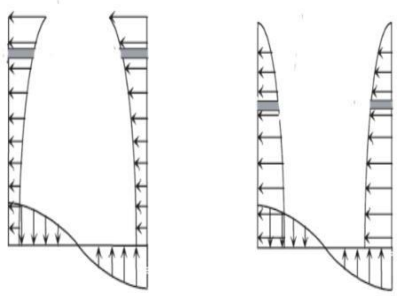

Figure 5. Hydrostatic forces assigned on the walls of the tank

The hydrostatic pressure which is to be assigned is calculated based on the following parameters:

liquid considered	Water
Time step size	0.0005s
Compressibility of fluid	Incompressible
Density of Water	1000 kg/m^3
Poisson's Ratio	0.17

Table 1. Parameters considered Concrete

Design:

The required compressive strength for the building is assigned as 30000 KN/m2. The required yield strength for main reinforcement steel is given as415000 kN/m2. Add the elements required for the structure such as design beam, design column and take off.

Design of beams and columns:

For the design of beams, the concrete design is assigned to the beams which are parallel to x and z direction.

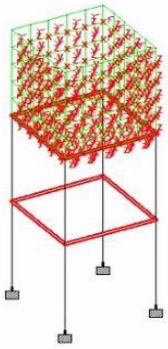

Figure 6. Design of beams

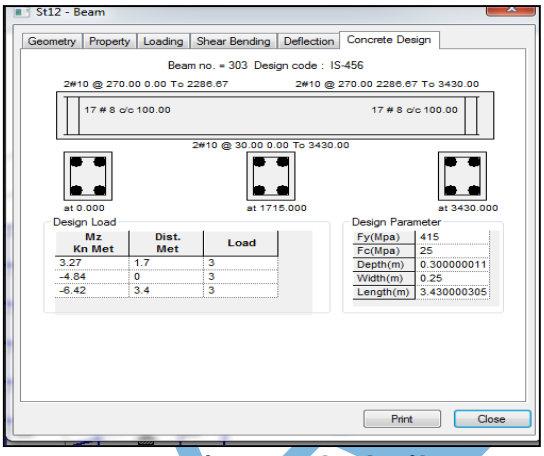

Figure 7. Reinforcement details of beam

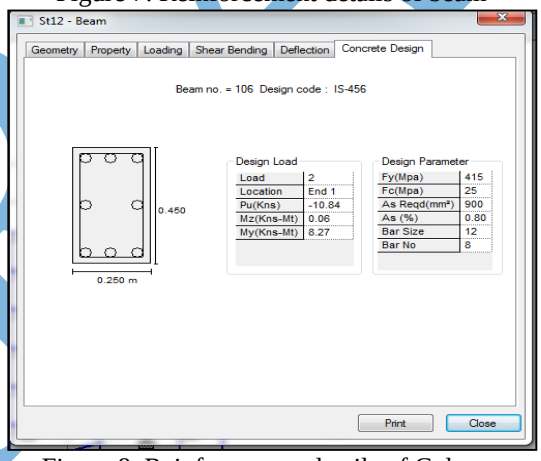

Figure 8. Reinforcement details of Column

IV. RESULTS AND DISCUSSIONS

Results from analysis of elevated water tank under hydrodynamic pressure including the effects of impulsive and convective pressure are discussed below. The maximum deformation were observed for the slab i.e., bottom surface of tank. Von mises stress contour was observed that the maximum stress is at the boundaries of tank.

Stresses in walls of tank

From the observation of stresses at various sections of the tank, it is clearly evident that the maximum stresses are encountered at the boundaries i.e., at the walls of the tank. This is due to the pressure exerted by the liquid as a result of impulsive and convective excitation on the walls. Wall Stress shown below are with the inclusion of hydrodynamic forces for liquid filled up to4.5m.

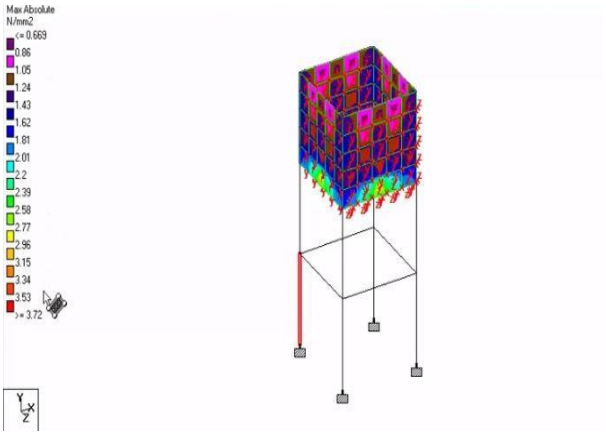

Figure 9. Stresses on walls

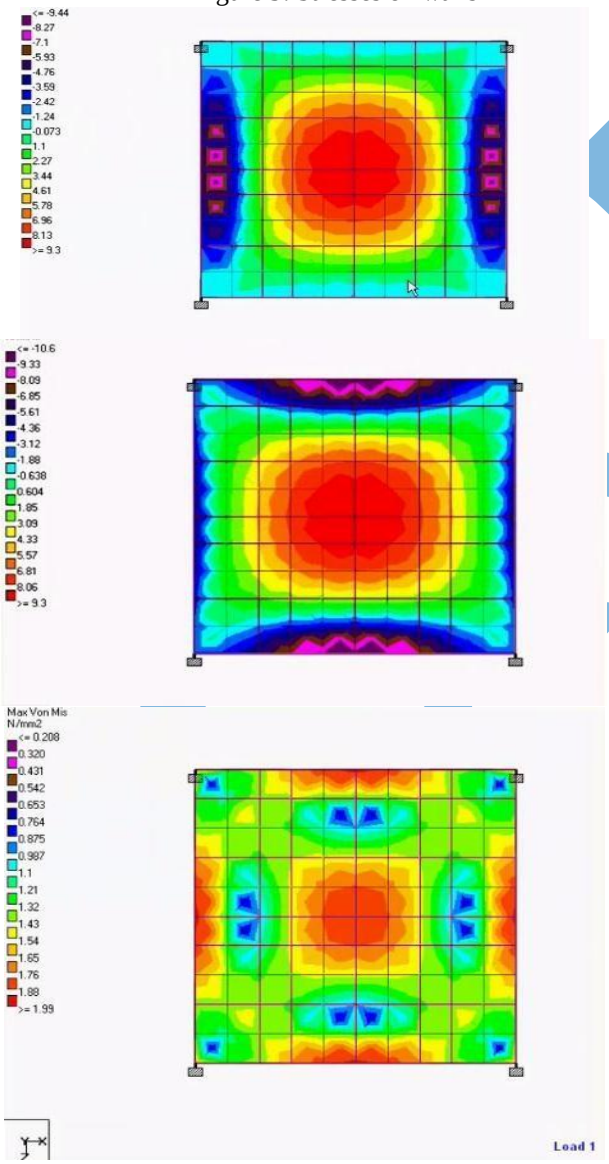

Figure 10. Stresses on walls in X,Y & Z Directions

From the observation of stresses at various sections of the tank, it is clearly evident that the maximum stresses are encountered at the boundaries i.e., at the walls of the tank. This is due to the pressure exerted by the liquid as a result of impulsive and convective excitation on the walls.

V. CONCLUSIONS

The analysis of elevated water tank is carried out with the effect of sloshing due to convective excitation and the other parameter of impulsive excitation which generates pressure inside the tank. With the analysis carried out in STAAD the following are the conclusions drawn:

1. The pressure exerted by the liquid on the boundaries of tank due to excitation is to be taken into account as this creates a greater stresses on the walls and base slab of the tank.
2. The base shear calculated under seismic condition varies with the liquid storage in the tank. Analysis shows that the base shear and base moment in full storage condition are greater than compared to empty tank condition.
3. Provision for free board helps liquid in the tank to oscillate freely which reduces pressure on the boundaries of tank.
4. Apart from the external excitation due to earthquake effect, Also the sloshing effect is to be taken into account for design of elevated water tank structures, without which sudden failure of structure happens.
5. The stresses as seen in the above figure, has a clear understanding that it is dependent on the parameters like intensity of external excitation i.e., earthquake, its time period, free board provision, slosh intensity which varies with the liquid fill.

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