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Structural Behavior for Composite Cylindrical Tank under Seismic Load

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Abstract:

This paper focuses on the structural behavior of composite cylindrical(Glass-polyesters) tank. The boundary conditions of the tank fixed along the coordinate system (x, z) and is free in y-axis. In this work used four composite cylindrical tank were different filling ratio by oil (10,9,6,4and 3)m and determine the maximum stress, maximum compressive stress and maximum wave height during first natural vibration period and compression between them by the Finite Element Method(Ansys software).

1- Introduction:

Cylindrical tanks with different shape and size are used in the chemical and petrochemical industries. Among the different types of shells, cylindrical shells are particular importance. Researchers have been trying to changes on the sidewall and material of these shells to increase their resistance against the load and decrease their weight. Variety of tanks that used in different industries has caused that design and installation of these reservoirs is very important. In the recent researches, El Damatty et al.[1] developed a numerical model to predict the dynamic response of flexible conical tanks. The model was based on a coupled shell-boundary element theory with assumption of decoupling between the sloshing component and the shell. Dynamic behavior of three models of steel cylindrical reservoirs containing fluid modeled using ANSYS software with applying the finite element method is studied by Mansouri and Aminnejad[2]. In this modeling, features of a cylindrical reservoir containing 0.9 height of liquid is used which its fluid is considered to be incom-pressible and viscose. Sweedan and El Damatty[3] carried out some experiments to identify the vibration modes of liquid-filled conical tanks. Amabili[4–6] performed some theoretical and experimental works on the nonlinear vibrations of fluid-filled cylindrical tanks and analyzed the effects of boundary conditions, large deformations and imperfection on the dynamic characteristics of the tank. Recently, Karagiozis et al.[7] investigated the nonlinear vibrations of fluid- filled clamped circular cylindrical shells. Also, Zhou and Liu[8] studied the three-dimensional vibratory characteristics of flexible rectangular tanks partially filled with fluid using an analytical solution. In the field of fluid–structure interaction in composite tanks, there are relatively newer research works. DehghanManshadi and Maheri[9] are presented the results of numerical investigations on the effects of material degradation due to corrosion on the dynamic characteristics of ground-based, anchored, steel liquid storage tanks. Internal corrosion is considered as a time-dependent constant thinning of the wall, at locations in contact with residual water, water condensate, atmospheric oxygen and acid gases. Pal et al.[10] made a study on the sloshing dynamics in a fluid-filled laminated composite open cylindrical tank

and later accomplished their work assuming nonlinear free surface boundary conditions using finite element method. Larbi et al.[11] presented the theoretical and finite element formulations of piezoelectric composite shells of revolution filled with compressible fluid. In the present study, the finite element method along with the modal analysis technique used to derive the equations governing the structural dynamics of the laminated composite tank. The dynamic behavior of cylindrical open top ground-supported water tanks is investigated by Moslemi and Kianoush[12]. The main focus of this study is to identify the major parameters affecting the dynamic response of such structures and to address the interaction between these parameters.
In this study, the vibration of the cylindrical tank used in the industry is examined. The tank is made of glass-polyester to obtain the maximum stress and compressive stress is the purpose of this study. To finding the effect of maximum wave height for four types of composite cylindrical tanks. It was different filling ratio by oil.

2- Finite Element Modeling:

2-1- Geometry and mechanical properties :

The basic materials properties determined are displayed in Table 1
The SOLID46 element in the finite element package ANSYS used for modeling and analysis of composite materials. The shell99 element was used for meshing the tank . in other hand, solid187 element was meshed the oil. The cylindrical tank contains oil with density of (970 kg/m^3). The geometry of the tank (Diameter, D =20m, Height ,H=12m and thickness ,t=8mm)

Table 1 mechanical properties for composite material (glass-polyester)

Mechanical properties	Glass-polyester
E_1 (Mpa)	24800
E_2 (Mpa)	4485
G_{12} (Mpa)	1466
ν_{12}	0.302
ν_{21}	0.059
V_f	0.3
Efor polyester(Mpa)	2958.93

2-2 Boundary Conditions:

Figure 1 shown the boundary conditions of the tank that one bases fixed and another base fixed in directions *x* and *z* coordinates. We’ve meshed the model, after determining the properties of the used material. The elements should considered along the thickness of the tank. Figure (1-1). illustrates the thickness in direction of an element.

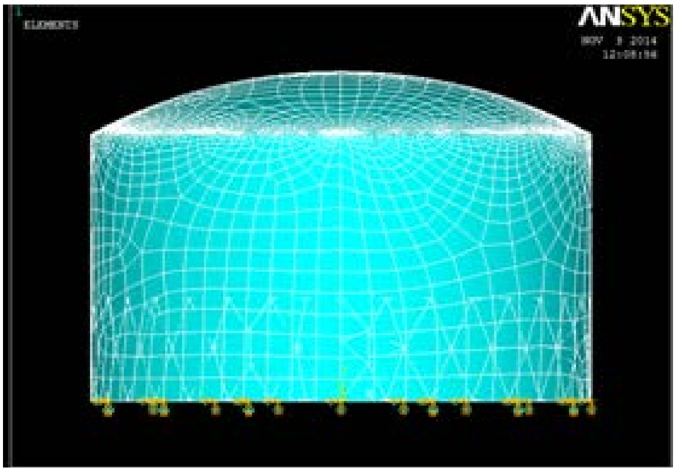


Fig. 1-1 boundary condition for composite cylindrical tank

2-3- Ansys Results:

The FEM analysis results focus on the generated principal stresses and the maximum wave height resulting from earthquake loading. Figures(1-2 to 1-5 show the two principal stresses (σ1 and σ2) and Figures(1- 6 and1- 9) the maximum wave height of the tanks. Table 2 summarizes the maximum values of the stresses (tensile and compressive) and the maximum wave height as well as the first natural vibration period of the studied tanks.

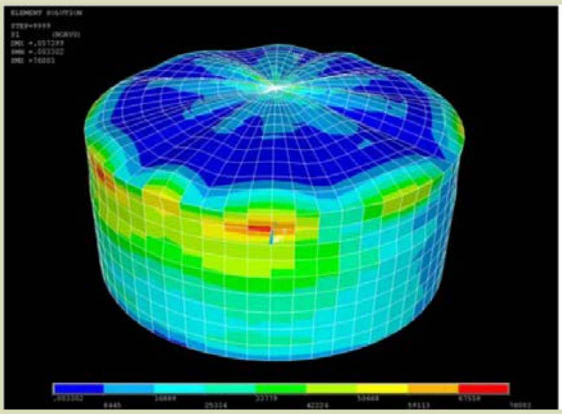


Fig.(1-2) Principle stress for tank (1) under seismic load

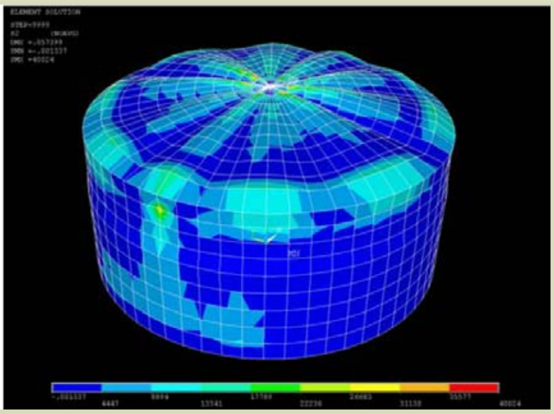


Fig.(1-3)2nd principle stress for tank (1) under seismic load

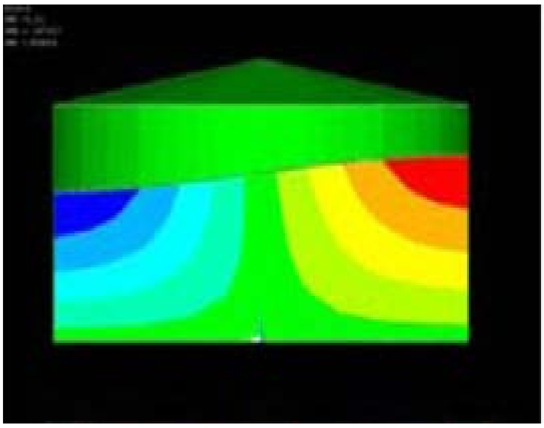


Fig.(1-8) Wave height for tank(2) under seismic load

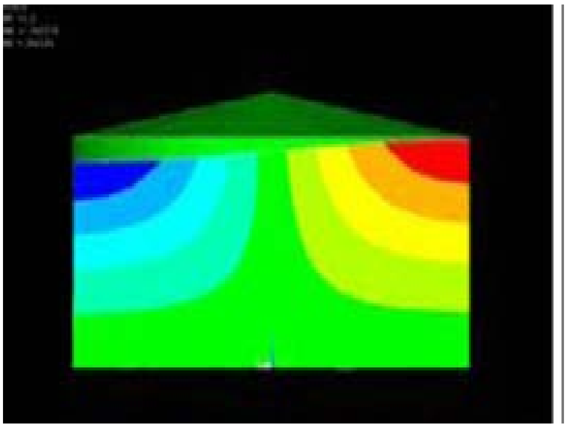


Fig.(1-9) Wave height for tank(1)under seismic load

Table (2)Maximum tensile stresses, compressive stresses and wave height due to

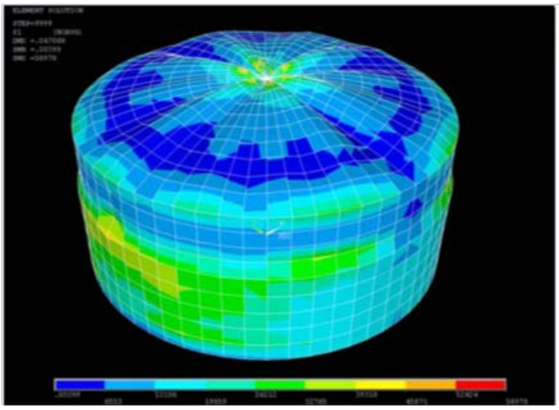


Fig.(1-4) principal stress for tank

(3) under seismic load

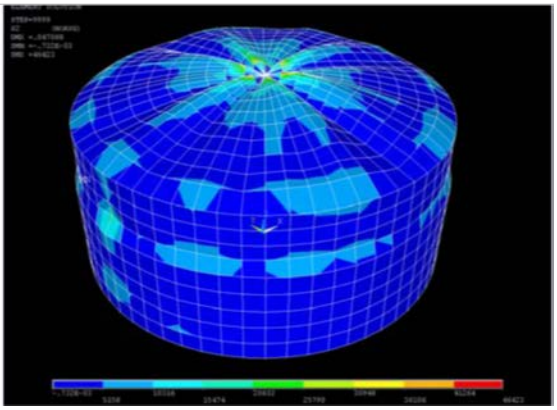


Fig.(1-5) 2nd principle stress for tank (3) under seismic load

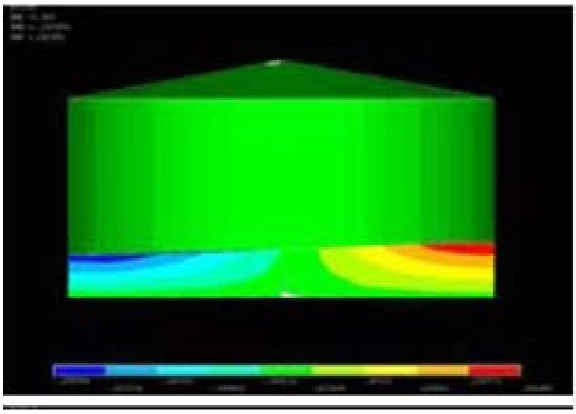


Fig.(1-6)wave height for tank(4) under seismic load

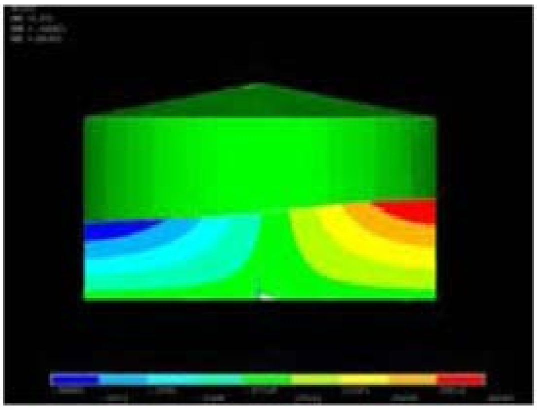
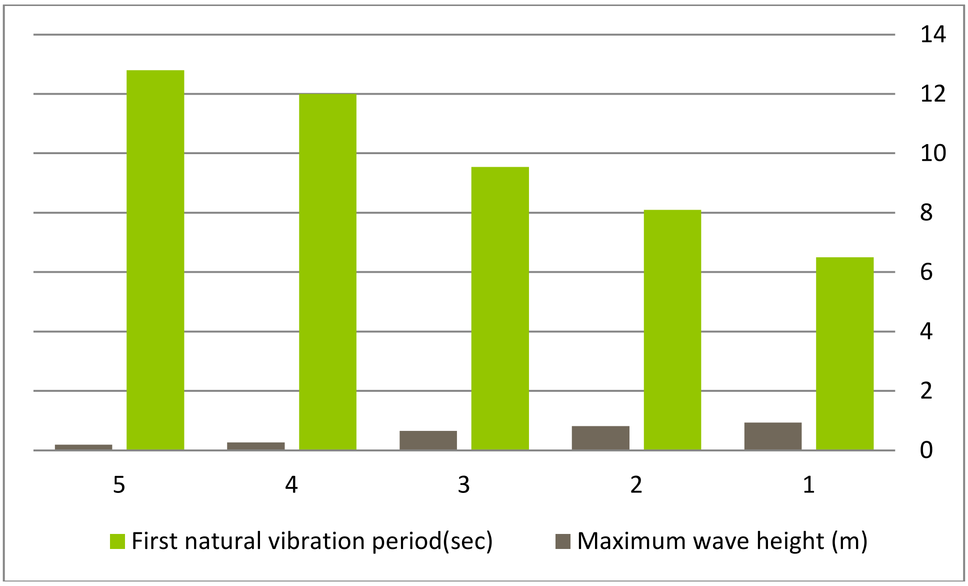


Fig.(1-7)wave height for tank(3) under seismic load earthquake loading presented together with the first natural vibration period of the analyzed tanks (FEM analysis).

Tank	Oil level	Maximum tensile stress (MPs)	Maximum compression stress(MPs)	Maximum wave height(m)	First natural vibration period (sec)
1	12	262.8	4.8	0.93	6.5
2	9	210	11.6	0.82	8.10
3	6,4	178	11	0.65	9.54
4	3	98	17	026	12
5	2	89	15	0.18	12.9



Fig(1-10) maximum wave height with the first natural vibration of period of the analyzed composite tanks (FEM).

Conclusions:

the tensile stresses increase with the increase of oil level, whereas more mass is being vibrated and the hydrodynamic forces are greater. The location of maximum tensile stress is close to the oil surface, because it is influenced by the pressure resulting from the generated wave. The compressive stresses on the other hand generally reduce with increasing oil level The maximum wave height increases with the oil level, as a result of the reduction in the sloshing period as shown (1-10). It should also be noted that the first natural vibration modal shape for each analyzed case is very similar to the figures depicting the maximum wave height (Figure 1-7 and Figure 1-8).

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