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Soil influence on partially buried tanks during land explosions

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Abstract: ***Explosion is considered a sudden load on structure that may result in destructive and unrecoverable consequences. In this article we will study the role of soil in vicinity of concrete tank to lower the influence of explosion. In this study, LS-DYNA (one of the strong modelling programs) has been used for modelling the explosion. The results show that when the mass of explosive matter increases to 3750 KG, the pressure on the soil is about 19.5 times the highest pressure on the tank and which illustrates the role of soil on lowering the influence of pressure.***

Keywords: Explosion, Tank, Soil, LS-DYNA.

I. Introduction

Considering the important effect of shock wave during explosive loading on thin layers and also the significant effect of using mediate environment during transmission of impulse resulted from explosion to the work piece, studying the effective elements in transmission of shock wave such as mediate environment features, play an important role in better understanding the shaping processes during explosion. This issue, lead to evolution of common methods and improvement of explosive shaping processes. The purpose of most researches in this field is to find the function of forces during explosive procedures, mediate environment and structural shape change and also determining the yielding pressure of structure. In 2006, Ganni et al. carried out an experiment subjected as “the explosion on a concrete and reinforced slab”. They designed and constructed a concrete reinforced slab of 10000*10000*70 cubic millimeter dimension that had a pressure resistance of 40 MPa. They inserted TNT explosive material in a 3 meter distance from slab and after explosion; they provided graphs to show the amount of pressure [i]. In 2007, an explosion of a 5000 kg TNT with a distance of 40 and 68 meters from one concrete and reinforced block was numerically simulated through LS-DYNA program. In this article this model has been utilized for evaluating the accuracy [ii]. In 2009 Lio carried out a study on dynamic analysis of an explosion loaded tunnel. Their simulation was a finite element study with increasing the TNT in different layers of soil. They produced their numerical results in tension graphs on the tunnel by dispersing them in soil and finally receiving their effect on tunnel. Their numerical study was based on soil thickness change, tunnel depth increase or soil elasticity module changes. In fact they succeeded in numerical simulation with four increases of TNT layers and receiving this effect on aforesaid changes [iii]). Hussain (2010) nonlinearly analysed a single free degree system under explosion load. The explosion wave of a single free degree system is studied in two methods. First is based on displacement as per time that which is time history. The second is that the explosion wave can be studied in two phases of linear and nonlinear. As a summery, Hussain loaded a frame under explosion and provided results based on time history of acceleration and force [iv]. In 2011, Luccioni and Araoz numerically studied the critical points of a concrete structure by LS-DYNA and AUTODYN. The material model they used to simulate concrete was RHT. This material model has been severally used in researchers’ works. The reason is that in order to indicate the features of concrete, high amount of data must be imputed in the program, this results in improvement of program capabilities for illustrating results as outputs. Luccioni and Araoz used this material model to illustrate concrete and he succeeded in providing a good numerical simulation for a concrete structure under explosion load [v]. In 2012, Jang et al, numerically modelled the TNT explosive material near water and steal. The program that they used was LS-DYNA and their method was ALE. They modelled explosive material inside water containing steal and provided TNT explosion effects through graphs [vi]. Hang and Wilford carried out a research subjected as “simulation comparison with MMALE method using LS-DYNA program”, in which the explosion experiment was carried out on a concrete structure [vii]. In 2012, Yan et al numerically simulated the effect of TNT on a steal pipe inside soil using LS-DYNA. Their numerical model method was ALE. The material they used for modelling was soil, TNT, steel pipe, water and air. Finally the pressure load on pipe was presented through graphs [viii]. In 2013, Ramasoami et al. numerically analysed a block building under explosion load. Their aim was to show yielding and deflection under explosive load. They showed building deflection in slabs and on walls through program [ix].

Cheng et al. in 2013, used LS-DYNA Mapping 2D to 2D technology can effectively increase the numerical model size of which scaled distance can be extended from 0.09 to $0.61 m/kg^{1/3}$ [x].

Identifying the amount of destruction during explosion in structure is not possible through lab methods due to high costs, thus the scholars have decided to use numerical modelling. In the current research, we study the modelling of explosion around a partially buried concrete tank. The criteria for evaluating the behaviour for concrete tank in response to the explosion is the pressure load to the tank and the purpose of this article is to study the reductive role of soil on the pressure yielded to the tank. The research method is as follows, first, the experiment carried out in this field will be modelled through LS-DYNA to evaluate the accuracy of numerical modelling and analysis; then the model of utilized material is selected from program library for numerical simulation and finally, the simulation and numeric results are provided.

II. Material and Methodology

• Research Method

This project is a rectangle concrete of 4000 cubic meter volume that is designed in two sections that are geometrically symmetric and have 9 square columns in each section. The columns are punched to the tank ceiling and the walls in vertical view are trapezoids with lower side of 70 cm and upper side of 40 cm. almost half of tank is buried in sand and around the tank is buried with layers of 30 cm soil and compressed. Whole of tank is covered with soil layers (the tank is half berried). Figure (1) is a numerical simulation of half buried tank.

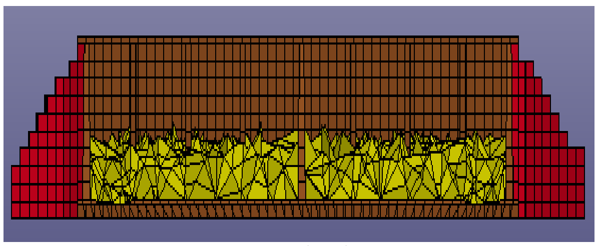

Figure (1): Numerical simulation of half buried tank.

Soil, air, TNT, concrete tank and water are modelled in the simulation. Boundary conditions and initial conditions are determined using geometry and content of the problem. The boundary conditions are in a way that all floor nods of the tank are fixed in all directions. In the initial conditions, the TNT load was changed three times (750 kg, 1500 kg and 3750 kg). The selected element is a Solid 164 type which is a three dimensional element with six sides, eight nodes and 9 degree of freedom. This element is used in explicit problems. The ALE simulation was used and in order to connect the elements the following command was used: CONSTRAINED_lagrange_IN_SOLID. The number of all elements for tank simulation when the TNT weight was 1500 with no water were a total of 33692 elements, from which 16705 were air elements, 5932 were tank elements, 5 were explosive material element and 11050 were the soil elements.

• Accuracy Analysis

In this section we are going to simulate the explosion load on a reinforced concrete in South Australia. The important point in this simulation is the modelling of reinforcements inside concrete. However, we can use proper models that play the role of reinforced concrete and obtain proper results but we clearly can gain a far better solve through modelling the reinforced concrete. The simulation program in this study is LS-DYNA.

In addition, in this section, the LBE method was used for numerical simulation of experiment; which is based on Lagrange.in this simulation, total of 6912 elements were simulated, from which 3744 elements were BEAM, and 3168 elements were SOLID. In this study, the simulation was carried out by a material model named as Johnson Helmkoeist. Figure (2) shows the pressure load on concrete block for 5000 kg through simulation and experiment. This pressure is 710 kPa in peak which is highly acceptable regarding experimental results. The low error justifies the use of numerical simulation by this program. In this experiment, 5000 kg of TNT produced 700 kPa pressures to a concrete structure with reinforcement no. 16. In addition, this example were also analysed by AIR3D and also another method based on Dynamics of Fluid CFD named as CONWEP; as we see in figure (3) the results of numerical and experimental methods are significantly accurate. Figures (2) and (3) illustrates the time depended pressure on the concrete block in the simulation and the experiment the pressure diagram is in fact the impact force that reaches maximum in a moment and then reduces. The peak happens in 0.04 second at 710 kPa.

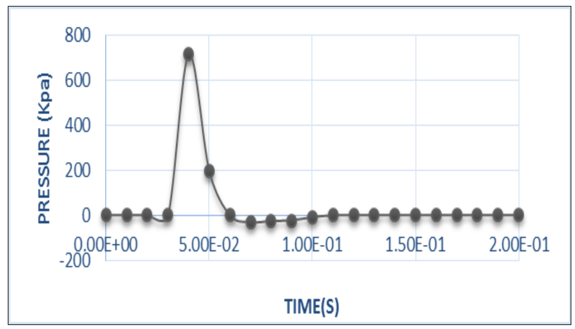

Figure (2): Pressure load on concrete block for 5000 kg through simulation and experiment.

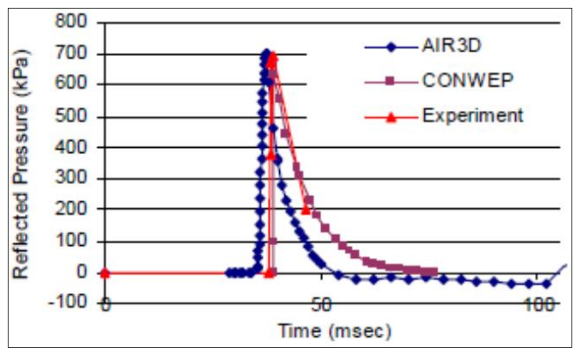

Figure (3): The accurate results of numerical and experimental methods.

III. Result

Figure (4) shows the maximum time dependent pressure on concrete tank with 750 kg TNT. In this case, the maximum pressure is 3.35 MPa which happens 0.0268 seconds after explosion. In addition, the explosion pressure reduces after almost 0.03 second.

Figure (5) shows Maximum pressure on soil elements for 750 kg of TNT. The maximum pressure on this stand is almost 156 MPa, which happens 0.07 seconds after explosion and reduces after 0.025. In addition, we can see that the maximum pressure on soil elements is about 47 times bigger that maximum pressure on structure.

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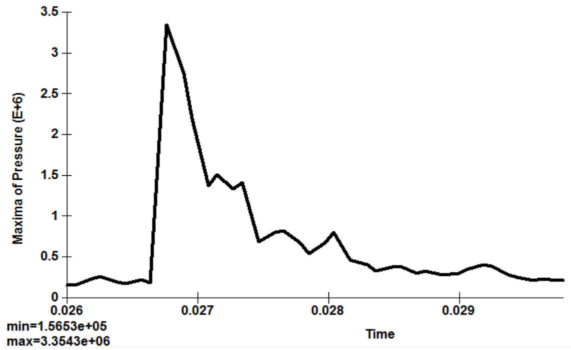

Figure (4): The maximum pressure on concrete tank with 750 kg of TNT.

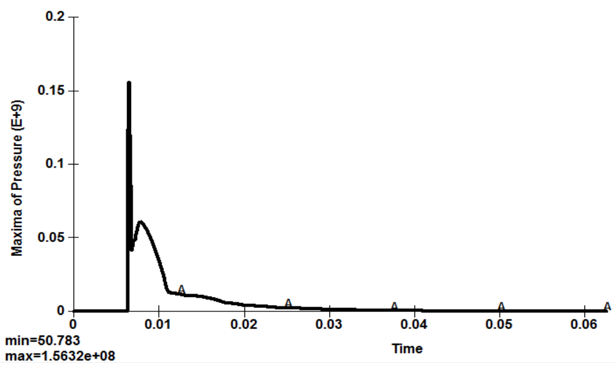

Figure (5): The maximum pressure on soil with 750 kg of TNT.

Figure (6) shows the maximum time depended pressure on concrete tank with 1500 kg TNT. In this stand, the maximum pressure is 10.25 MPa which happens 0.034 seconds after explosion. In addition, after 0.038 seconds the pressure reduces. Also, the maximum pressure increases three times compared to 750 kg TNT.

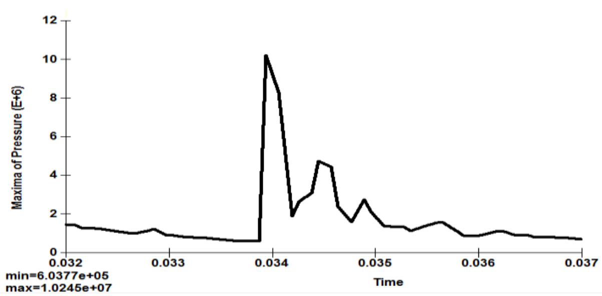

Figure (6): The maximum pressure load on concrete tank with 1500 kg TNT.

Figure (7) shows the maximum pressure on soil elements with 1500 kg explosive material. The maximum pressure on soil elements is about 226 MPa, which happens 0.008 seconds after explosion and reduces after 0.03 seconds. In addition, compared to previous example (1500 kg TNT), the maximum pressure load to soil respectively increases 31, 14, 20 percent during maximum pressure and during reduction of pressure.

Figure (8) shows the maximum time dependent pressure on concrete tank with 3750 kg TNT. In this state, the maximum pressure is 13.59 MPa which happens in 0.0215 seconds after explosion. In addition, after 0.0245 seconds, the pressure of explosion reduces.

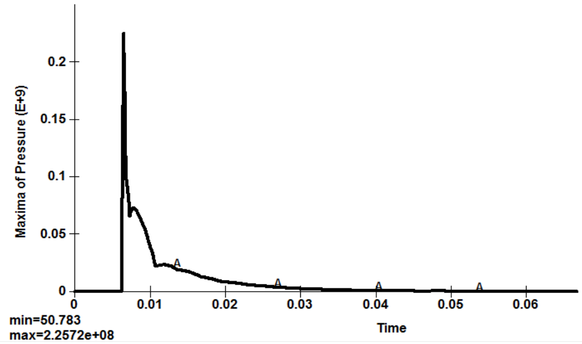

Figure (7): the maximum pressure load on soil with 1500 kg explosive material.

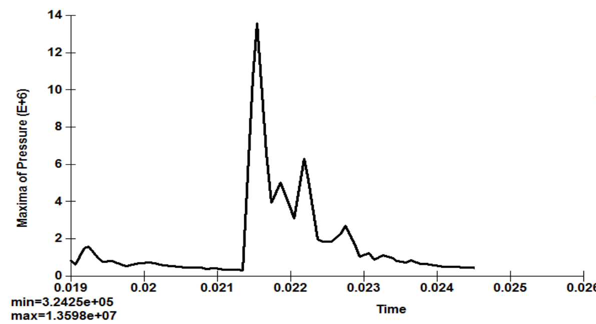

Figure (8): the maximum pressure load on concrete tank with 3750 kg TNT.

Figure (9) shows the maximum pressure on soil elements with 3750 kg TNT. Maximum pressure on soil elements is about 263 MPa; which happens 0.008 seconds after explosion and reduces after 0.035 seconds. This amount of pressure on soils is about 19.5 times bigger that maximum pressure on tank and shows the role of soil in reducing the pressure.

As we see from figures, most of pressure from TNT that was meant to load on tank was loaded on soil thus the soil plays a protective role supporting tank against the explosion. If we did not use soil, the same amount of energy would have loaded on tank; in that case the damage to tank would have been significant.

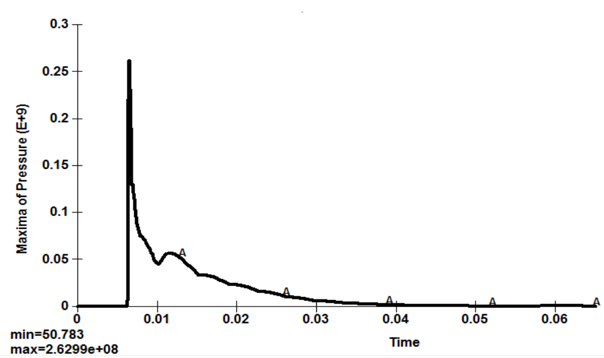

Figure (9): The maximum pressure load on soil with 3750 kg TNT.

IV. Conclusion

- The low rate of error shows the accuracy of numerical simulation carried out by LS-DYNA compared

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to experiment for simulation explosion load on earth tanks.

- Using twice explosion material weight by Johnson Helomkoeist model, the maximum pressure tripled. In addition, the maximum pressure on soil was respectively 31, 14 and 20 percent during reaching peak and after reducing.
- When explosive material weight was increased to 3750 kg, the pressure on soil increased 19.5 times the maximum pressure on tank.
- It is clear that we cannot create a structure completely immune to explosive loads.

References

i. Ghani Razaqpur, A., Tolba, A. (2007). Contestable Blast loading response of reinforced concrete panels reinforced with externally bonded GFRP laminates. Science Direct, part B, 38 - 535-546.

ii. Tanapornraweekit, G., Haritos, N., Mendis, P., & Ngo, T. (2007). Modelling of a reinforced concrete panel subjected to blast load by explicit non-linear FE code. The Australian Earthquake Engineering Society.

iii. Liu, H. (2009). Dynamic analysis of subway structures under blast loading. Geotechnical and Geological Engineering, 27(6), 699-711.

iv. Hussein, A. T. (2010). Nonlinear analysis of SDOF system under blast load. European Journal of Scientific Research, 45(3), 430-437.

v. Luccioni, B., Aráoz, G.] (2011). Erosion Criteria for Frictional Materials under Blast Load. Mecánica Computational, XXX, 1809-1831.

vi. Wang, Z., Lu, Y., & Bai, C. (2011). Numerical simulation of explosion-induced soil liquefaction and its effect on surface structures. Finite Elements in Analysis and Design, 47(9), 1079-1090.

vii. A-man, Z., Wen-shan, Y., & Xiong-liang, Y. (2012). Numerical simulation of underwater contact explosion. Applied Ocean Research, 34, 10-20.

viii. Yan, S., Xu, Y. R., & Chang, H. Y. (2012). Numerical Simulation of Dynamic Response of Buried Pipeline by Ground Explosion. In Earth and Space 2012 (pp. 1159-1166).

ix. Ramaswamy, S. N., & Arunmohan, A. M. (2013). Static and Dynamic Analysis of fireworks industrial buildings under impulsive loading. IJREAT International Journal of Research in Engineering & Advanced Technology, 1(1).

x. Cheng, D. S., Hung, C. W., & Pi, S. J. (2013). Numerical Simulation of Near-Field Explosion. Journal of Applied Science and Engineering, 16(1), 61-67.