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EVALUATING THE EFFECTS OF UNDERGROUND EXPLOSIONS ON STRUCTURES

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ABSTRACT

The response of a concrete frame 2-bay 2-storeyed structure for underground TNT explosion is studied in this paper. The type of soil is limited to sandy soils and the behaviour of the structure is studied by changing charge weight of TNT at certain intervals of 10, 15, 20, 35, 50,75and 100tons. For the charge weight of 10tons the depths of explosion below the ground level are taken as 1.5m, 2.5m, 3.5m. ANSYSAUTODYN software is used to model the structure, soil and explosion. The response is obtained in terms of pressure, velocity and stress.

KEYWORDS: *underground explosion; charge wt; depth of charge wt; TNT, ANSYS AUTODYN; finite element model;*

I. INTRODUCTION

Due to the sudden accidental explosions of storage materials below the ground surface or any intentional attacks can cause damage to the nearby structure. Keeping in view of the probability of underground explosion to take place, the study on response of concrete structure to underground explosions is necessary to protect the structures.

The ground motions generated due to the underground explosions cause damage to nearby structure [1]. The ground motion decreases rapidly when it propagates away from the charge centre and increases with increasing of charge wt [1]. The response of the structure is evaluated by peak particle velocity (PPV), peak particle acceleration (PPA), peak displacement (PD) [2]. Granular material model for soil represents dry sand is used to model the sand. To evaluate the dynamic response under blast loads, the strain dependent concrete (RHT strength model) is suitable [2]. Euler 3D multi material is used to fill the TNT in sand [10] and flow out boundary conditions is used to restrict material to flow [10].

II. MODELING OF BLAST SIMULATION

The numerical simulation of underground explosion is done by using ansysautodyn. The fig 1 shows the model in autodyne 3D. The soil below the ground surface is taken as sand. The TNT of10 tons charge wt is placed at the distance of 2.5m below the ground surface. The frame of the starting point is considered at 4m epicentre. Flow out boundary conditions is applied to the sand to restrict the material flow out. And Euler 3D multi materials are used to create the model. To model the frame conc. -35mpa is used. The storey ht of the frame is 3m and the bay width is 3m. The section properties of columns and beams are 300mm*300mm.

The materials of Sand for soil, Air, TNT, and conc-35 mpa for concrete frame are loaded from the material library of AUTODYN to carry the simulations.

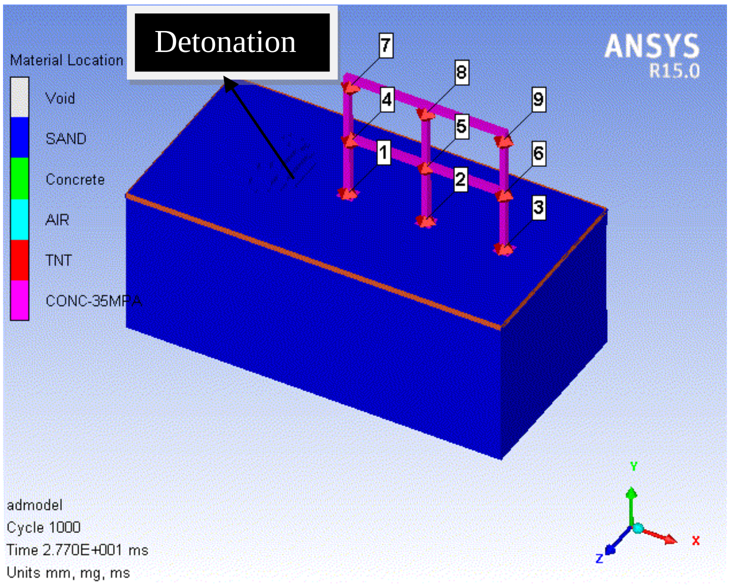

Fig 1 model in autodyne 3D

III. PROPERTIES OF MATERIAL MODELS

3.1. Air:

Equation of state is used for the air is ideal gas. Internal energy is simply proportional to temperature. Ideal gas Equation of state written as

$$p = (\gamma-1)\,\rho\, e \qquad (1)$$

in which p is the hydrostatic pressure, ρ is the density and e is the specific internal energy. γ is the adiabatic exponent, it is a constant (equal to $1+R/c_\nu$).where constant R may be taken to be the universal gas constant R_0 divided by the effective molecular wt of particular gas and c_ν is the specific heat at constant volume. The values constants used for the air presented below table 1.

TABLE 1 Properties of air

Equation of state : ideal gas	
Parameter	**value**
γ	1.4
Reference density ρ_a	1.2E-3 g/cm^3
Reference temperature T_0	288.2 k
Specific heat c_v	717.3 J/kg k

3.2. TNT:

The equation of state for both detonation and expansion of TNT in conjunction with " jones-Wilkins-lee to model the un reacted explosive to model is lee-tarver. The JWL EOS can be written as

$P = c_1\,(1-\theta/r_{1\nu})\, e^{-r}{}_{1\nu} + c_2\,(1-\theta/r_{2\nu})\, e^{-r}{}_{2\nu} + \theta e/\nu$

where p is the hydrostatic pressure $\nu = 1/\rho$ is the specific volume, ρ is the density, C_1, r_1, c_2, r2and ω (adiabatic constant) are constants and their values have been determined from dynamic experiments and are available in the literature for many common explosives. The values used for TNT are presented below table 2.

Table 2 Properties of TNT

EOS: jones- wilkins-lee(JWL)	
Parameter	**value**
Refrence density ρ	1.658 g/cm^3
c_1	3.73E8 kpa
c_2	3.73E6 kpa

r_1	4.15
r_2	0.9
θ	0.35
C-J detonation velocity	6.93E3 m/s
C-J energy/unit volume	6E6 kj/m^3
C-J preassure	2.1E7 kpa

3.3. Sand:

A compaction equation of state combined with a MO granular strength model is used for Soil that represents dry sand. Compaction equation of state is an extension of the Porous equation of state that allows more control over loading/unloading slopes. In linear porous Equation of state the plastic compaction path is defined as a piecewise linear function from which unloading and reloading can occur along an elastic line Using this model, a material initially compacts from $\rho=\rho_0$ along an elastic path defined by the differential equation.

$$dp/d\rho = c_{limit}^2$$

MO Granular Model is an extension of the Ducker -Pager model that takes into account effects associated with granular materials. In addition to pressure hardening, the model also models density hardening and variations in the shear modulus. Material properties for Soil are consigned in Table3

Table 3 Properties of sand

EOS: compaction				**Strength: MO granular**			
Reference density ρ = 2.64 g/cm^3							
Pressure (kpa)	Pressure (kpa)	Pressure (kpa)	Pressure (kpa)	Pressure (kpa)	Strength (kpa)	Density (g/cm^3)	Shear modulus (kpa)
0	0	0	0	0	0	1.674	7.69E+4
4.5E+3	4.5E+3	4.5E+3	4.5E+3	3.4E+3	4.23E+03	1.746	8.6E+5
1.5E+4	1.5E+4	1.5E+4	1.5E+4	3.5E+4	4.4E+04	2.086	4E+6
3E+4	3E+4	3E+4	3E+4	1.0E+05	1.24E+05	2.147	5E+6
6E+4	6E+4	6E+4	6E+4	1.8E+05	2.26E+05	2.300	7.77E+6
10E+4	10E+4	10E+4	10E+4	5E+05	2.2E+05	2.572	1.5E+7
2E+5	2E+5	2E+5	2E+5	Hydro tensile limit		2.58	1.6E+7
3E+5	3E+5	3E+5	3E+5	P_{min} = -100 kpa		2.635	3.6E+7

3.4. Conc 35MPA

Concrete has an inhomogeneity and porosity. Due to this concrete behaves as a non linear compression material. To model the concrete p-α equation of state and polynomial equation of state with RHT concrete strength model used.

The polynomial EOS is:

$$P = A_1\mu + A_2\mu^2 + A_3\mu^3 + (B_0 + B_1\mu)\,\rho 0e + T1\mu + T_2\mu^2 + B_0\rho_0 e\ldots.. \quad (3)$$

Where μ = compression = $\rho/\rho_0 - 1$

P_0 = solid zero pr density

e is internal energy per unit mass. A_1, A_2, B_0, B_1, T_1, T_2 are material constants

The p-α EOS is described as

$$P = (\alpha\,\rho\,e) = \text{with } \alpha = 1 + (\alpha_\rho - 1)\left(\frac{p_s - p}{p_s - p_e}\right)^n \quad (4)$$

In which p_e = initial compaction pressure; p_s = solid compaction pr; n is compaction exponent; α is porosity.

The values used for concrete are presented below.

Table 5 Properties of concrete

EOS: P –α		T_{ref}	300 k
Porous density ρ	2.314 g/cm^3	C_V	653.99 j/kgk
P_e	2.33e+04 kpa	**Strength: RHT concrete**	
P_s	6.0e+6 kpa	Shear modulus G	1.67 E+7 kpa

n	3	Compressive strength f_c	3.50e+04 kpa
Solid EOS: polynomial		Tensile strength (f_t/f_c)	0.10
A_1	3.527e+07 kpa	Shear strength(f_s/f_c)	0.18
A_2	3.95e+07 kpa		
A_3	9.0e+06 kpa		
B_0	1.22		
B_1	1.22		
T_1	3.527 e+07 kpa		
T_2	0		

IV. Results And Discussions

The structure response is obtained in terms of velocity, pressure, and stress at gauge points. Average response of the structure through over all gauge points is presented in this paper instead of response at all gauge points.

Figs 2,3,4shows the time histories of velocity , pr and stress of concrete frame for 10 tons TNT blast at 1.5m 2.5m 3.5 below the ground surface respectively. And Fig 5 shows the variation of variables with respect to the charge wt. fig 5, 6, shows the variation response with charge wt.

Time histories for 10 tons TNT blast at 1.5m, 2.5m, and 3.5m below the ground surface.

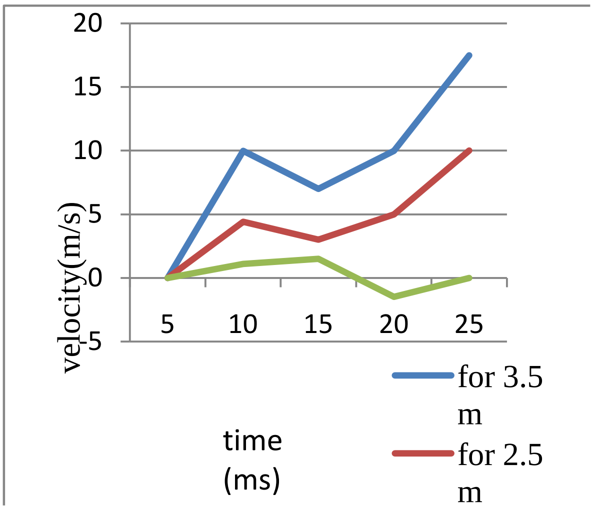

Fig 2 Velocity time history

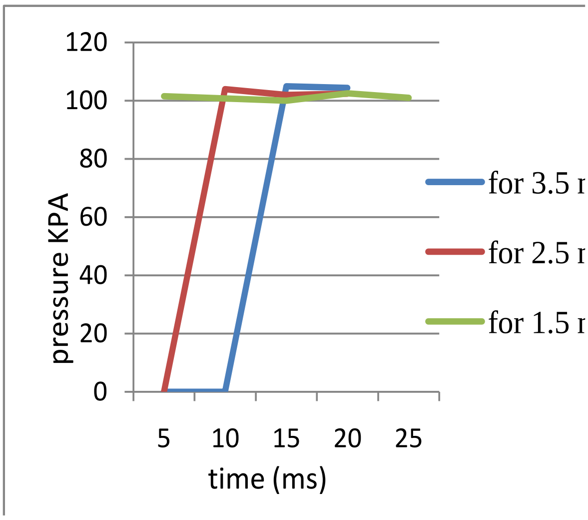

Fig 3 pressure time history

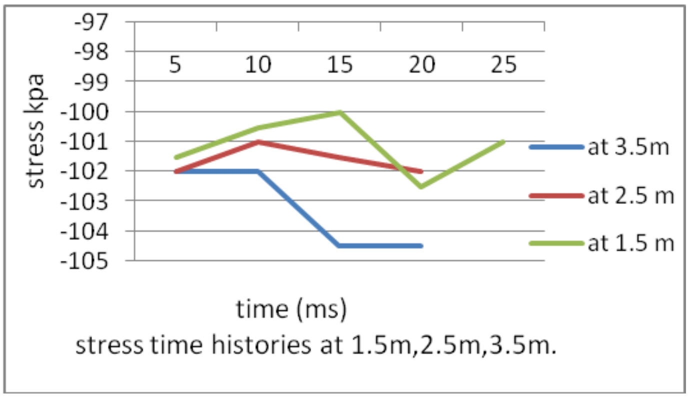

Fig 4 Stress time history

Peak values of variables for different blast loading

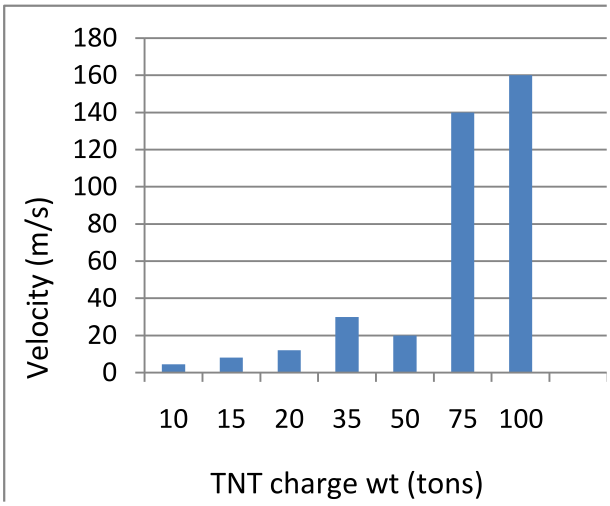

Fig 5 peak velocity values for TNT charge wt

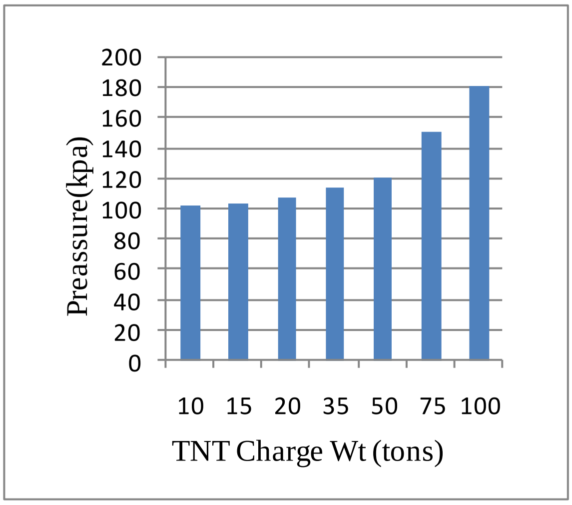

Fig 6 peak pressure values for TNT charge wt

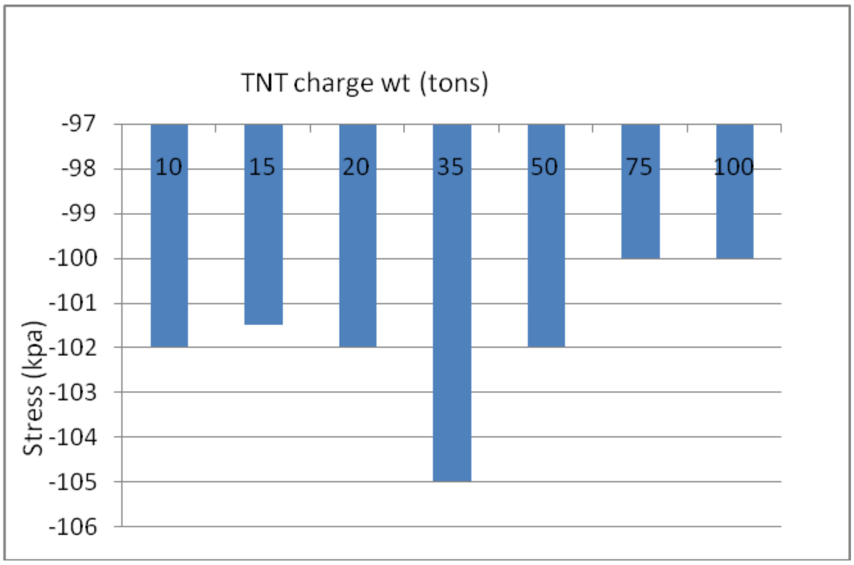

Fig 7 Variation peak pressure for TNT charge wt

4.1 Discussions

Due to the blast of 10 tons TNT at 1.5 m below the ground level, velocity at a gauge point in the structure is found to be 18 m/s and decreased gradually to 10 m/s ,1.5m/s for explosion at 2.5m, 1.5m respectively.

From Fig.3.it is evident that there is some time lag for pressure to act on the structure. For an explosion of 10 tons at 1.5m,2.5m there is no indication of pressure up to 5ms of time and blast pressure went up to 107kpa and 104 kpa after 5ms.The blast pressure is found to be 100kpa for a blast of TNT at 3.5m below the ground level.

From Fig.7.it is clear that for an explosion of 35tons of TNT the maximum stress is observed and it is close 105Kpa.

With the increase in the charge weight velocity of the structure is increasing gradually. The peak velocity of structure is found to be 160 m/s and the blast pressure on the structure is 180kpa for an explosion of 100 tons TNT at 2.5m below the ground surface.

V. CONCLUSION

- The response of the concrete frame is decreased with increasing the depth of the charge wt below the ground surface**.**
- The response of the concrete frame is increased with increasing charge wt

- Peak values of velocity, pressure, and stress of 10 tons at 2.5 m depth are 10 m/s, 112kpa and 101kpa respectively.
- The response of the first storey is high than the 2nd storey of frame.

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