Journal of Structural Engineering and Geotechnics,
5 (2), 45-49, Spring 2015

Assessment of Subsurface Explosion caused by Tunnel Construction in Urban Areas

Hossein Haghighi manesh[a], Mohammad Azadi[b*]

[a] M. Sc. Student, *Department of Civil Eng, Qazvin Branch, Islamic Azad University, Qazvin, Iran*
[b] Assistant Prof, *Department of Civil Eng, Qazvin Branch, Islamic Azad University, Qazvin, Iran*

Received 2 March 2015, Accepted 17 June 2015

Abstract

Nowadays, tunneling in urban areas is a common activity for a variety of transportations such as subways, water supply, lifelines and sewers that may require blast operations. The characteristics of stress waves of the blast are quite different from earthquake waves. The blast waves are usually of high frequency content, short duration, equality of amplitudes in horizontal and vertical directions and large range of magnitude from ten to thousands of the gravitational constant. However few papers can be found to discuss about the effect of soil characteristics under blast loading. In this paper, numerical models based on finite element method is used to simulate stress wave at soil sites under explosion effect in an underground linear chamber and then characteristics of the ground movement and the explosion effect on soil-structure interaction is analyzed. In this study, numerical results of area deformations in every region are compared together and parameter sensitivity of the soil is analyzed. Results presented in this paper can be used in a more detailed assessment of ground motion effect on structures.

Keywords: Subsurface explosions, dynamic settlement, ground vibration, Peak particle velocity.

1. Introduction

An explosion is a rapid release of energy and can happen in air, on the Earth's surface, underground and underwater. Typical example arises from chemical and nuclear explosives [1]. With regard to construction increase of underground spaces such as subway tunnels, sewage and underpasses, it can be seen that that the explosives are used in many cases. Damages of nearby structures to high frequency blast ground motion are an important concern in designing structures and blasting. Preliminary studies on the effects of underground explosion on buildings was performed in the United States of America by Rockwell at 1927 and then other people such as Thoenen and Windes during 1930 to 1940. Their study represented the first major effort to establish damage criteria for residential structures and developed a generalized propagation law for ground vibrations [2]. Ground particles oscillate in response to vibration wave in the blasting operation. This oscillation is measured in particle velocity. The maximum rate is the peak particle velocity (PPV). Many existing regulatory guides on blast induced vibrations for structure are often based on PPV. They were established from empirical correlation between observe damage and recorded peak particle velocities during field blast tests [3]. In most of the empirical relations that presented by various researchers to predict PPV of the blast in determined distance, soil material is not considered. For example, the following relations can be mentioned:

$$PPV = 100\times Q^{0.8}\times D_s^{-1.6} \quad (1)$$
$$PPV=0.396(D_s/Q^{1/3})^{-1.1455} \quad (2)$$
$$PPV = 113\times Q^{0.8}\times D_s^{-1.6} \quad (3)$$

Equation 1 [4] and Equation2 [5] can be used to estimate PPV where Q is the TNT charge weight in Kilograms and D_s is the distance in meters measured from charge center and in Equation 3 [4] units are in terms of pounds and feet. Few studies can be found in which blast wave propagation in the three – phase soil model [6], behavior of soil [7] and effect of sand layer on blast induced ground excitations [8] is discussed.

In this research, regarding this fact that the soil profile between the source of the explosion and structures is an important factor in the effect of waves on structures, the effect of soil parameters using Mohr Coulomb model on the recorded PPV at substructure, foundation displacement, and surface settlement is investigated. Finite element method is used in the calculations and Plaxis (8.2) software that in soil areas and dynamic analysis has shown good capabilities has been used in this study.

* Corresponding Author Email: azadi.mhmm@gmail.com

2. Numerical simulation

Using plane strain method in software, it is assumed that the building Length is much longer than the width and length of the building is along the length of the explosive area (Figure 1).
Soil thickness and width of model are considered 24 m. and 65 m. (Figure 2). To reduce the effect of reflected waves, boundaries of the model are defined as the absorbent boundary (Figure 2). 15-node triangular elements and 5-node beam element mesh is used to soil and structure. The explosions are generated in the finite element model by applying a Sinusoidal pulse in all direction of explosion chamber (Figure 3).
To obtain the effect of soil parameters, at first the reference model is defined with the soil characteristics in Table 1 and then the effect of each soil parameter on the base model is assessed. In this study, the building has four floors and a basement with a width of 6 meters and a height of 12 meters above ground and 2 meter underground. Material properties are shown in table 2.

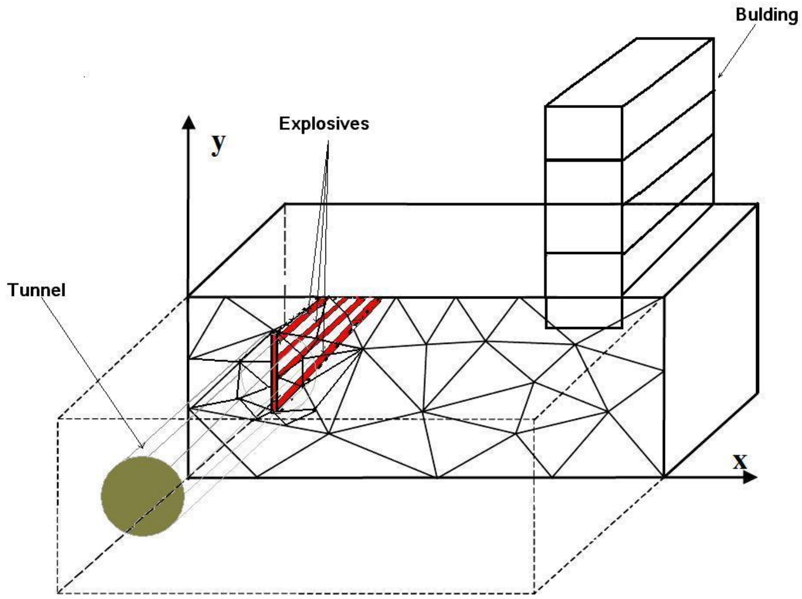

Fig. 1 Configuration of underground blast site

3. Effect of soil parameters on PPV

At the dynamic provocations such as an earthquake or an explosion, effect of soil parameters in Moher Colomb model, Young’s modulus Poisson’ ratio on variation of PPV at building foundation are investigated and depicted in figure 4. The results are summarized below:

- The cohesion of soils has minimal effects on PPV.
- The most influential factor in the amount of PPV on structure foundation is soil elasticity. The rate of effectiveness with less than 100 MPa Young's modulus is a faster process.
- Increasing the internal friction angle of soils cause further PPV on structure foundation. Changing the friction angle between 0 to 40 degrees, PPV grows 66.9 percent.
- Increased soil Poisson's ratio increases recorded PPV.

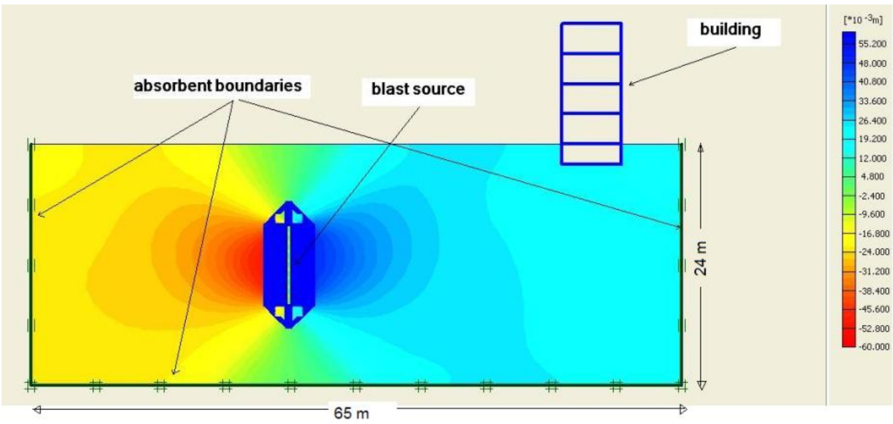

Fig. 2 Structure of the models and soil displacements at 0.25 second

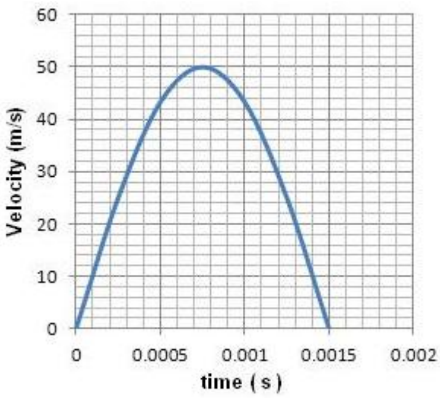

Fig. 3 A short pulse

Table I

Soil characteristics of the reference model

Poisson's ratio	*Young's modulus (kN/m3)*	*Density saturated (kN/m3)*	*Density unsaturated (kN/m3)*	*Friction angle (degree)*	*Cohesion (kN/m2)*	*Rayleigh*
0.3	3.81×10^5	20	18	30	20	0.015

TABALE II

Material properties of the building (plate properties)

Parameter	*Name*	*Floor/Wall*	*Unit*
Material model	-	Elastic	-
Normal stiffness	EA	5×10^6	kN/m
Flexural rigidity	EI	9000	kNm^2/m
Weight	W	5.0	kN/m/m
Poisson ratio	υ	0	-
Rayleigh damping	α, β	0.01	-

4. Foundation displacement

Figure 5 represents a comparison of the effect of soil parameters on the overall shift at the structural foundation in 0.25 seconds. The results are the following:

- The cohesion of soils has minimal effects on foundation displacement. Changing the value from 0 to 10 kN/m^2 displacement of foundation is increased only 11 percent.
- The maximum displacement of the structure foundation followed in 0.25 seconds occurred on soil with 50 MPa Young's modulus.
- Soil friction angle is the most important factor affecting the building foundation displacement and displacement in soil with 40 degree friction angle is double in comparison with 0 degree friction angle soil.
- Poisson's ratio up to 0.3 approximately doesn't influence on the foundation displacement and in soils with higher amount 20% reduction is observed.

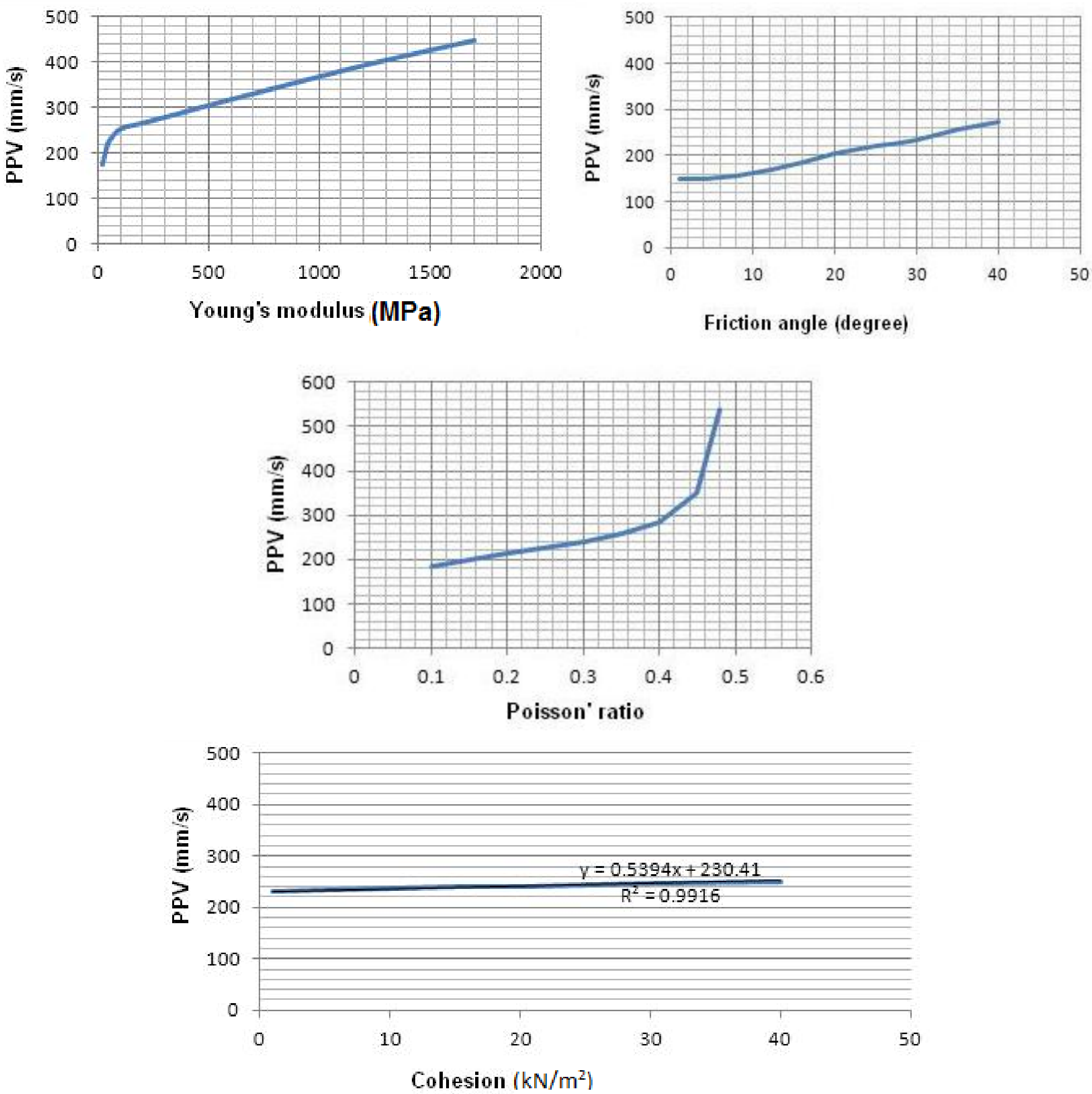

Fig. 4 The relationship between PPV in the structure foundation and Young's modulus, Friction angle, Poisson' ratio and Cohesion of soil.

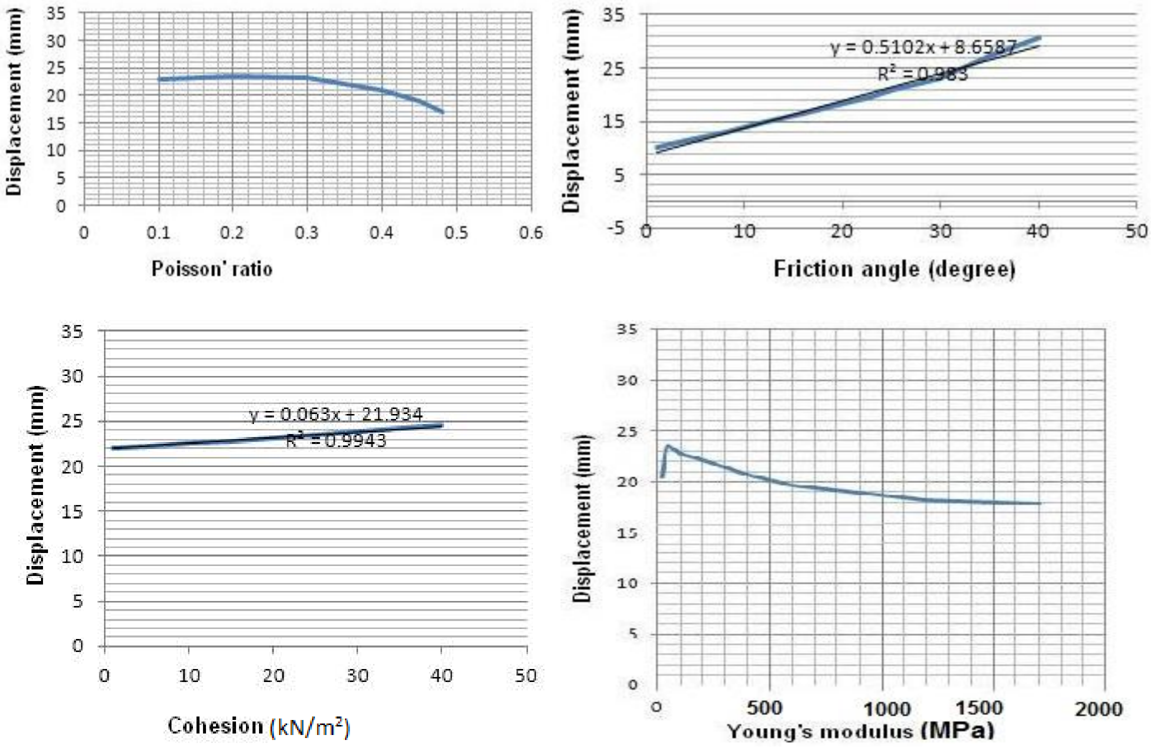

Fig. 5 The relationship between total displacement of the structure foundation and Poisson' ratio, Friction angle, Cohesion and Young's modulus of soil.

5. Conclusion

Simulation has been carried out to find the effect of soil characteristics on PPV and on structure foundation displacement.

Considering that all of the existing formulas for predicating the amount of damage caused by underground explosion had been prepared without regard to the effect of soils, this study can be used for development of those.

Results show that Young's modulus is the most important factor in the effectiveness of blast vibration on buildings. The rate of effectiveness with less than 100 MPa Young's modulus is a faster process. Also, cohesion of soils has the least affected on PPV and foundation displacement but increasing the internal friction angle of soils cause further PPV on structure foundation. Changing the friction angle between 0 to 40 degrees, PPV grows 66.9 percent and displacement in soil is double.

References

[1] Bangash MYH (2009). Shock, Impact and Explosion Structural Analyses and Design. United Kingdom: Springer, pp. 671-750.

[2] Nicholls HR, Johnson FC and Duval WI (1971). Blasting vibrations and their effects on structures. US Department of Interior Office of Surface Mining and Enforcement, Bulletin 656.

[3] Wu C, Hao H(2005). Numerical study of characteristics of underground blast induced surface ground motion and their effect on above –ground structures. Part I. Ground motion characteristics. Soil Dynamics and Earthquake Engineering 25(2005), pp.27-38.

[4] Jimo CL & Jimeno EL & Carcedo FJA (1995). Drilling and blasting of rock s. Geo mining technological institute of Spain .

[5] Hao H, Wu c, Zhou Y(2002). Numerical analyses of blast-induced stress wave in a rock mass with anisotropic continuum damage models Part 1: Equivalent material property approach. Rock mechanics and Rock engineering (2002) 35 (2), pp.79-94.

[6] Wang Z, Hao H and Lu Y(2002). Numerical simulation of blast wave propagation in soil mass. wave propagation – moving load – vibration reduction proceeding of the wave, Yokohama, Japan.

[7] An J (2010). Soil behavior under blast loading. Ph. D. thesis, Department of Civil Engineering, University of Nebraska-Lincoln.

Wu C, Hao H(2004). Numerical simulation of structural responses on sand layer to blast induced