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AN IDENTIFICATION OF GROUND VIBRATION IN NORTH-EAST OF THAILAND BY BLASTING METHOD

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Abstract

This research reports an identification of safety distance for ground vibration, which has an effect on different types of structures in the Northeast of Thailand by blasting method. The data were collected from the fieldwork in the Northeast of Thailand through ground vibration by blasting method. The research results show that the heavier the blast, the higher the peak particle velocity in accordance with the distance. The lower frequency contributes to the accumulation. Further, the lower frequency will have a greater effect on structures than the higher frequency. This research can be used as a way to prevent the structures from the damage caused by blasting method and to help evaluate the safety distance for different kinds of structures to comply with the application of blasting method in the Northeast of Thailand. The data is based on the criteria of peak particle velocity and the frequency safe from ground vibration according to DIN 4150 proposed in Germany in order to control the peak particle velocity in the Northeast of Thailand and to achieve safety for different types of structures.

Keywords: Blasting, Ground vibration, Peak particle velocity, Safety distance, Scale distance.

1. Introduction

Nowadays the data underneath the surface can be identified or examined with more accuracy and precision. There are many methods to achieve such purpose, depending on the kind of data to look for and the data application. To illustrate, the data which are required for the identification of geographical features such as energy resources and petroleum can be examined by sending waves underground [1-3].

However, the choice of wave source depends on many relevant factors such as

Nomenclatures

a, b	Constant
D	Geophone array, m
D_T	Total geophone spread, m
d	Distance between explosion source and geophone, m
F_n	Natural frequency, s^{-1}
K	Soil coefficient
N	Standard penetration test, blow/ft
n, a, b	Geometric attenuation coefficient
Q	Blast weight, kg
SD	Scale distance, $m/kg^{1/2}$
X_1	Distance between first geophone and explosion source, m

Abbreviations

DIN	Standard Criteria for Blast Identification of Germany
PPV	Peak Particle Velocity
FFT	Fast Fourier Transform

the accuracy of the data, the depth of the data, the impact, the environmental features and cost. These factors will play a significant role in the decision of the users. Blasting method is effective in that it gives accuracy and precision but the energy from the blast can have an effect on structures due to ground vibration [4]. In some cases, the ground vibration will be absorbed by some mediums but each medium is different in terms of vibration absorption, resulting in a different effect on structures in the surrounding area of the blast. To consider the problem of blasting method and its effects on structures, there are some important variables, including peak particle velocity, amplitude and frequency. The variables, which are widely recognized and can be used to explain the damage to the structures are the peak particle velocity and the frequency. Still, to identify ground vibration in a close distance (safety distance), it is important to the frequency forms single spike pulse. However, when it is done is a far distance, the frequency will be in a sinusoidal wave, as shown in Fig. 1. This study aimed to propose safety distance from explosion sources using ground vibration equations.

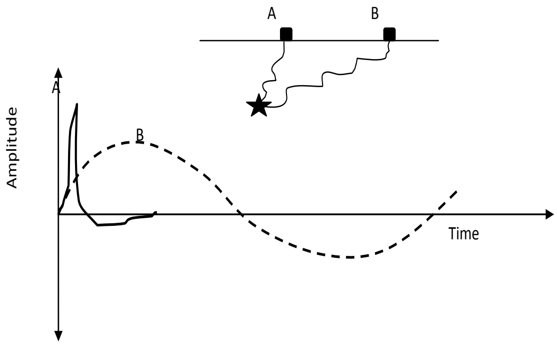

Fig. 1. Blast wave from the explosion source to the measuring place A (close distance) and the measuring place B (far distance) [5].

2. Ground Vibration

2.1. Blast wave from blasting method

When an object blasts, there will be shock energy and gas energy. Shock energy will send blast wave to ground layers, resulting in particles moving in the ground. The wave from the blast will move through Compression or Longitudinal wave (P-wave), through Shear or Transverse wave (S-wave), and Rayleigh or Vertical wave. As shown in Fig. 2, the energy from the blast wave will result in 67% Rayleigh wave, 26% Shear wave and 7% Compression wave [6]. Rayleigh wave is a big wave with the movement velocity of 0.9 of the shear wave and the shear wave velocity is about 0.6 times in comparison to the compression wave velocity.

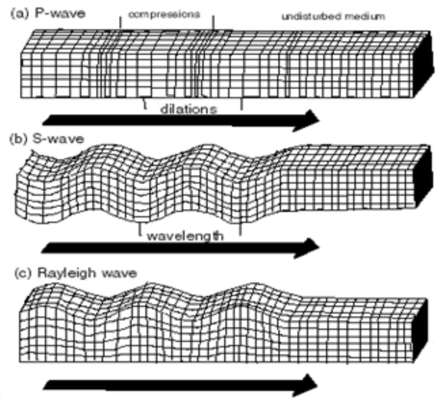

Fig. 2. Blast wave [6].

2.2. Effects of ground vibration

Ground vibration can have an effect on structures or buildings, depending on its intensity, duration and dispersion between ground and structures. The effect of the vibration depends on peak particle velocity (PPV) and frequency.

2.2.1. Peak particle velocity (PPV)

A study into the effects of ground vibration usually involves the vibration velocity of the medium through the medium so that the medium particles move. The movement of particles refers to vibration. The highest velocity of particle movement is called peak particle velocity with the unit of millimetres per second or inches per minute.

2.2.2. Frequency

The frequency of ground vibration can be determined using the times of vibration within 1 second (its unit is Hz) or the frequency as the reciprocal of the period [1]. Frequency, acceleration and period in the ground vibration will disperse through the medium, resulting in changes in the medium in the next layer. This continual dispersion will lead to effective absorption and rather than high frequency. However, the frequency and the velocity will depend on the wave, the acceleration and the distance. The vibration frequency ranges between 0.5-200 Hz. A low frequency will cause more damage than a high frequency because long distance means more expansion [1].

Many parts of structures will have their natural frequency between 4-12 Hz [7]. When the frequency of the ground vibration is close to the natural frequency of the structures, there can be damaged. The frequency of ground vibration by blasting method is usually dependent on geographical features of each area. In other words, hard ground will result in high frequency. However, each area has different geographical features and therefore, it is difficult to estimate whether the frequency will be high or low.

2.2. Standard criteria for blast identification

Standard criteria for blast identification of Germany (DIN 4150) [8] have been developed to identify the norm for the effects on structures, depending on peak particle velocity, frequency and type of structure, as shown in Table 1 and Fig. 3.

Table 1. Standard criteria for blast identification of Germany (DIN 4150) [8].

		Vibration velocity (mm/s) Foundation frequency		
Line	**Type of structure**	**Less than 10 Hz**	**10 to 50 Hz**	**50 to 100 Hz**
1	Building used for commercial purposes, industrial buildings and building of similar design	20	20 to 40	40 to 50
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20
3	Structures that, because of their sensitivity to vibration, do not correspond to those listed in lines 1 and 2 and are of great intrinsic value (e.g. buildings that are under a preservation order)	3	8 to 10	8 to 10

*For frequencies above 100 Hz, at least the values specified in this column shall be applied

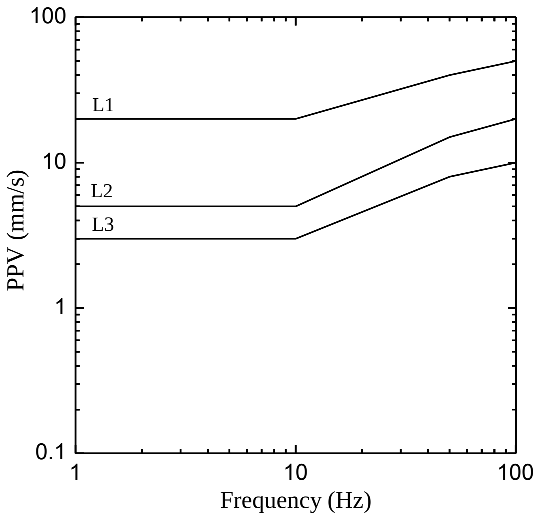

Fig. 3. Peak particle velocity and frequency which is safe for ground vibration according to Germany's criteria DIN 4150 [8].

3. Materials and Methods

3.1. General site information

3.1.1. Udonthani

The layer extends from ground surface to depth of about 4.2 m. It mostly contains silt mixed with very fine sand. The relative density measured using split spoon ranged between loose to medium state (Average Standard Penetration Test (N) about 39 blow/ft), and Very fine sandy clay layer (Average Standard Penetration Test (N) about 92 blow/ft) extends to depth of about 12 m from ground surface. The consistency ranged between medium to the hard state, and Silty very fine-coarse sand layer (Average Standard Penetration Test (N) about 150 blow/ft) is underlain the studied site to a depth of 32 m and underground water level at 2.42 m from the surface. The relative density ranged between very dense to medium state, as shown in Fig. 4.

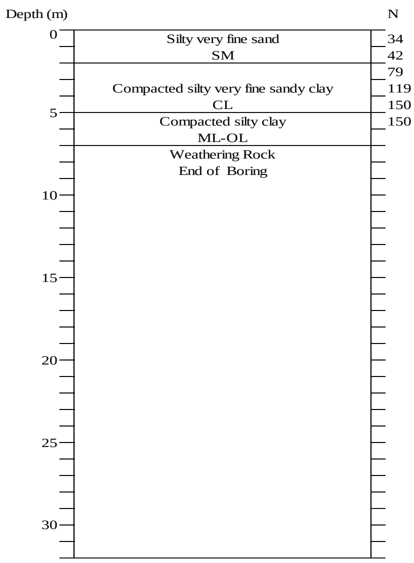

Fig. 4. Standard penetration test (N) and geological condition of Udonthani.

3.1.2. Mahasarakham

The layer extends from ground surface to depth of about 2 m. It mostly contains silt mixed with very fine sand. The relative density measured using split spoon ranged between dense to very dense state (Average Standard Penetration Test (N) about 17 blow/ft), and Compacted silty very fine sandy clay (Average Standard Penetration Test (N) about 29 blow/ft) is found beneath the top silty very fine sand layer extends to depth of about 4.5 m from ground surface. The consistency ranged in the hard state, and Compacted silty clay layer (Average Standard Penetration Test (N) about 102 blow/ft) is underlain the studied site to a depth of 6.45 m and underground water level at 2.6 m from surface. The relative density ranged in the hard state, as shown in Fig. 5.

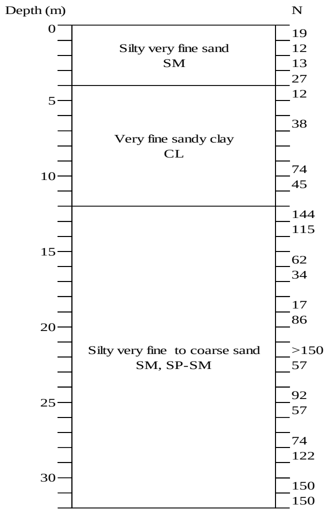

Fig. 5. Standard penetration test (N) and geological condition of Mahasarakham.

3.2. Blasting method

The data were collected at Udonthani and Mahasarakham province in the North-East of Thailand. The blast was in a single point. The type of explosive was emulsion high explosive (Emulex 700, Class 1.1D, UN0241), namely Emulex 700, as shown in Fig. 6. The weight of the charge and the depth of the hole were categorized as shown in Table 2.

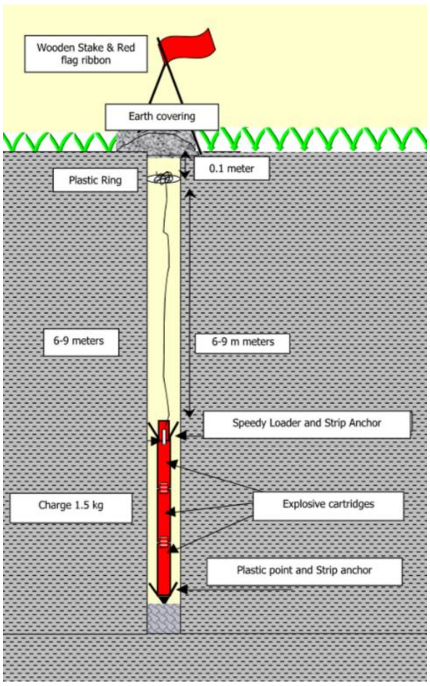

Fig. 6. Installing of seismic source (Emulex 700).

Table 2. Weight of charge and depth of blast hole.

Area	Charge weight (kg)	Hole depth (m)	Number of sample
Udonthani	1.5	6.0 -9.0	127
Mahasarakham	3.0	12.4	527

3.3. Geophone

Geophone was used to identify the ground vibration. There were 16 geophones in a vertical line (G1-G16). All of them were Gisgo SN4-4.5V from the United States of America. The natural frequency (F_n) is 4.5 Hz, as shown in Fig. 7. The data were recorded when there were ground vibration and this information was transformed into electrical current or voltage. The distance between the first geophone and the explosion source (X_1) was around 10-1000 meters and geophone array (D) was 20 meters. The total geophone spread (D_T) was 300 meters, as shown in Fig. 8.

Fig. 7. Geophone spike.

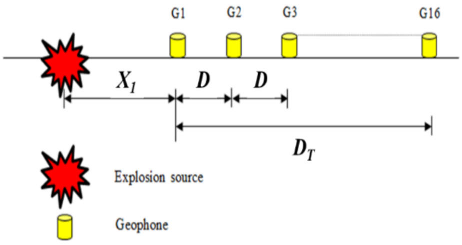

Fig. 8. Geophones set.

3.4. Data logger

Data logger received the signal from the geophone and recorded it at different times (NI 9205 16-Ch ±10 V, 250 kS/s, 16-Bit/ DSUB). There were around 2,000 values per second and these data were transferred to a laptop as shown in Fig. 9.

Fig. 9. Data logger.

3.5. Data processing

The ground vibration at different spots was identified by the data logger and the data were converted using Fast Fourier Transform (FFT) to measure peak particle velocity (PPV) and dominant frequency in each distance to make a comparison with the criteria suggested by DIN 4150. The vibration data from the field would be analysed using the estimation of PPV [9-11] and a graph to show the relationship between PPV and scale distance and weight would be drawn as shown in Eq. (1).

$$PPV = a(SD)^b \quad (1)$$

where *PPV* is peak particle velocity (mm/s), *SD* is scale distance (m) = $d/Q^{1/2}$ (d is distance (m) and Q is weight of charge (kg)), a is material damping, b is geometric damping.

4. Results and Discussion

Figures 10 and 11 reveal that the peak particle velocity decreases in relation to increase in distance. The ground vibration lost energy during the dispersion under the ground. The difference between ground layers resulted in the complexity of the vibration, probably leading to the reflection or the refraction of the wave as well as the absorption or reduction of energy. When the blast weight increased, the peak particle velocity and the distance increased (Figs. 12 and 14). According to these figures, the lightweight blast would result in the dispersion of frequency whereas the heavyweight blast would result in the accumulation of low frequency (Figs. 13 and 15). It should be noted that low frequency has a greater effect on structures than high frequency.

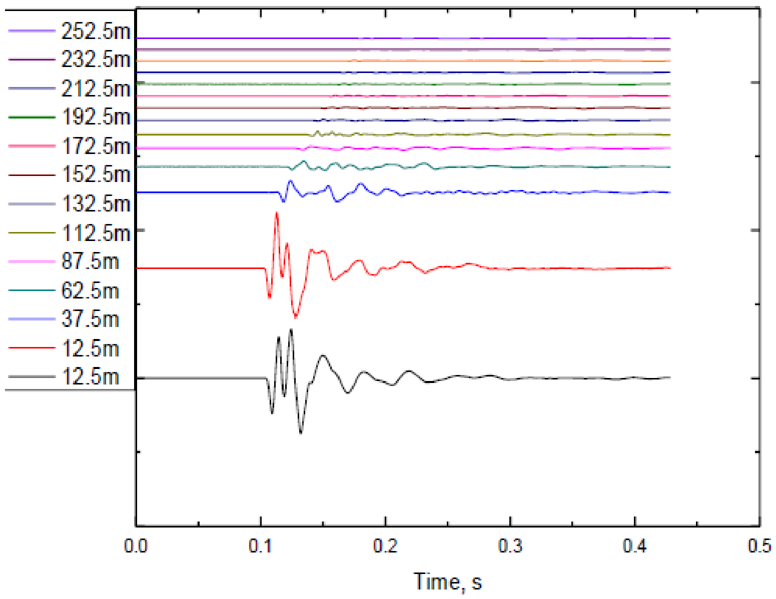

Fig. 10. Wave of the blast (1.5 kg charge) from one explosion.

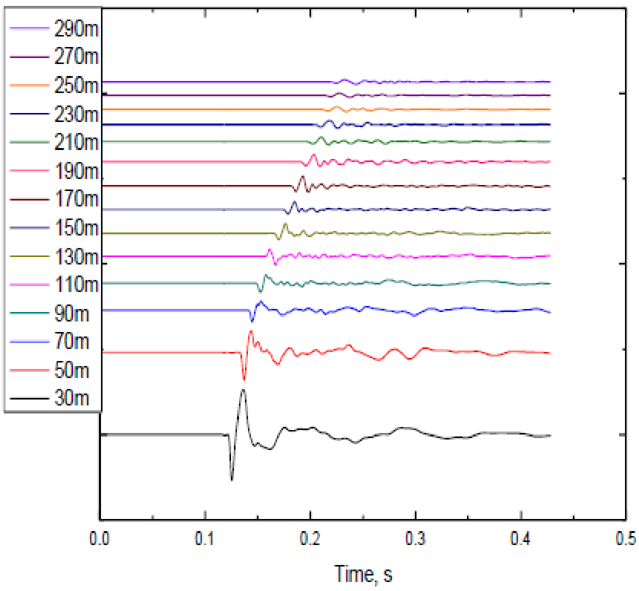

Fig. 11. Wave of the blast (3 kg charge) from one explosion.

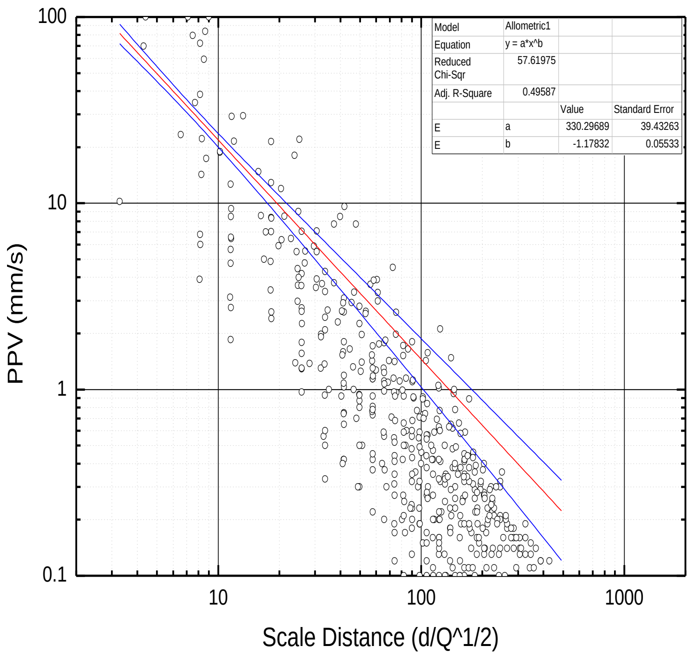

Fig. 12. Relationship between peak particle velocity and scale distance according to DIN 4150 (1.5 kg of explosive).

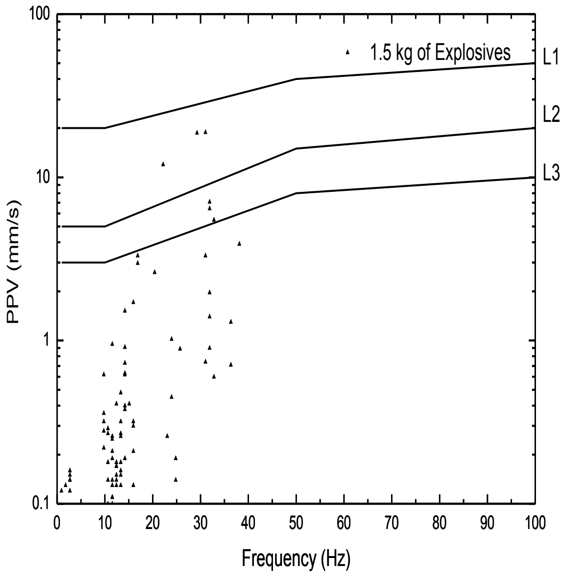

Fig. 13. Relationship between peak particle velocity and frequency according to DIN 4150)1.5 kg of explosive).

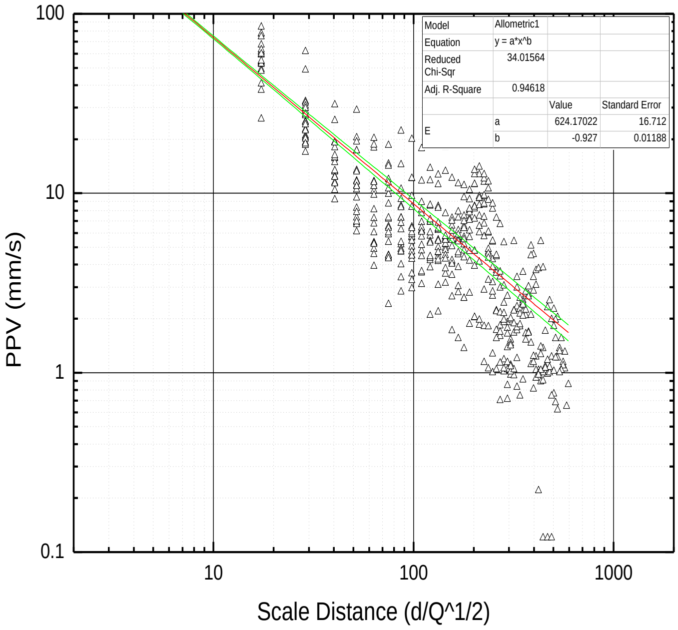

Fig. 14. Relationship between peak particle velocity and scale distance according to DIN 4150)3 kg of explosive).

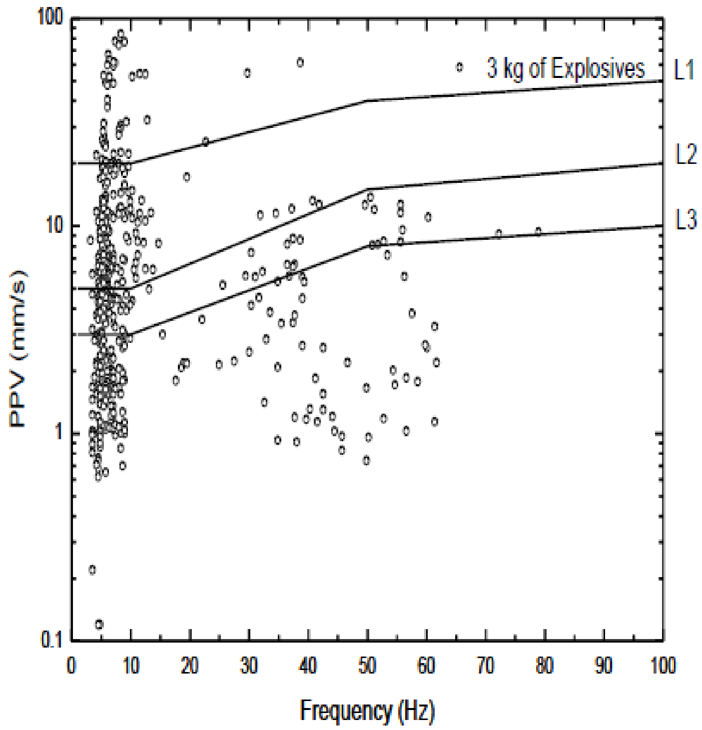

Fig. 15. Relationship between peak particle velocity and frequency according to DIN 4150)3 kg of explosive).

According to the results, an estimation of the ground vibration can be made out of the relationship between peak particle velocity and scale distance as shown in Eq. (1). Peak particle velocity depends on the weight of the blast as shown in Table 3. If the weight of the blast is heavy, the peak particle velocity can go further than the lighter blast. It also depends on the ground layers. This equation is suitable for the identification of ground vibration in the Northeast of Thailand.

Table 3. The values *a* and *b* with reliability of 95% according to the weight of blast.

Weight of blast (kg)	a	b	R-square
1.5	330.31	-1.177	0.50
3.0	624.18	-0.926	0.95

According to the data interpretation, the researcher set the safety distance for 3 types of structures according to DIN 4150 with a reliability rate of 95%. The calculation of safety distance based on the Eq. 2, in this case, depends on the lowest criteria of the standards for estimation. The peak particle velocity for the factories and enterprise structures (L1) is set at 20 mm/s. The peak particle velocity for residential structures (L2) is set at 5 mm/s. The peak particle velocity for ancient structures (L3) is set at 3 mm/s as shown in Table 4.

Table 4. Safety distance for different types of structures with reliability rate of 95.

Weight of blast (kg)	Ratio*	Safety distance according to types of structures (m)					
		L1	#L1	L2	#L2	L3	#L3
1.5	1.22	>10	>15	> 35	>45	>55	>70
3.0	1.73	>40	>75	>185	>325	>320	>560

*Ratio = Correction factor due to the weight of explosive

#L1, #L2 and #L3 = Suggested safety distance by type of structures

5. Conclusions

According to the research results, it can be seen that the peak particle velocity is related to distance and frequency. In other words, the peak particle velocity has the highest value near the blast and it decreases, as the distance is further due to the scale distance and the different ground layers according to the geographical features. The peak particle velocity from the equation can be used for a comparison with the standard criteria DIN 4150 set by Germany in order to control the peak particle velocity in the North-East of Thailand and to achieve safety for different types of structures.

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