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Smart Software Assessment of Effects of Rock Properties on Blast-Induced Ground Vibrations

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***Abstract:** The drilling and blasting method considered most economical method in civil and urban construction process. Ground vibrations are one of the major problem in blasting activity. Velocity of blast induced ground vibrations influenced by mainly three parameters such as properties of the rock mass properties, the explosive characteristics and the blast design and execution. In those parameters, rock mass properties of blasting area are unchangeable, so study of influence of rock properties very essential to minimize the effect of vibration on nearby structure. This study investigated the effect of rock strength parameters on vibration velocity. In this study, the blasting vibration monitored at a blasting site with different rock masses. This paper, presented a review on prediction models and rock properties influence on peak particle velocity. This paper also presented the relation between peak particle velocities different mines with their respective rock properties. This paper critical analysis on previous studies. This paper presented correlation between rock strength properties like compressive strength and tensile strength on vibration velocity.*

***Keywords:** Velocity, peak particle, blasting.*

I. INTRODUCTION:

The drilling and blast method is widely used in mining and construction industries for rock breaking. In fact 38-40 % explosive energy utilising to produce vibrations only (Hagan and Just, 1974; Berta, 1990). These blast induced ground vibration may cause damage to surrounding structures. The prediction methods given by various researchers are site-specific nature. The intensity of blast induced ground vibrations measured in terms of peak particle velocity (PPV). The distribution seismic energy produced by blasting activity majorly affected by design parameters like maximum charge per delay, delay time, burden, spacing, and its location (Pal 2005). According to Ghosh, (1983) "In mine bastings almost 40% of the blast induced energy reaches the surface a few meters from the blast canter in the form of vibrations which reflect in vertical longitudinal and transverse directions of the earth's surface". In recent times, blast induced vibration effects natural and man-made structures have gained considerable attention due to increase in threat from various man-made activities.

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Prediction of blast induced ground vibrations is becoming increasingly important because of the fact that blasting activity is spreading towards populated.

Therefore, investigation of influence parameters on PPV became a thrust area for researchers. The PPV value defined as the maximum values of the transverse, vertical, and longitudinal velocities of the propagating wave. According to research organizations and regulating authorities, the relationship between PPV and Scaled distance (SD) written as

$$V_{max} = K\ SD^{-b}\ \text{mm/s}$$

Where,

V_{max} = Peak Particle Velocity in mm/s;
SD = Scaled Distance ($D/Q^{1/2}$) for Ground Vibration
D = Distance of seismograph from blast site in m
Q = Maximum explosive charge per delay in kg
K & b = Site Constants

The site constants K and b, generally determined by blast experiments. This determined values used to predict the further vibration at same field only. Several researchers also proposed many empirical equations to predict PPV, in those few summarized below table-1.

The predictor models summarized in table-1 are site-specific equations. These models are not globalized. The constants in every equation are different in different site conditions, even if we maintain same type of explosive amount and distance. It proves that other than charge and distance there are some other factors also effecting the PPV.

Table-1: Summary of various empirical models

Researchers	Predictor equation
Langefors & Kihlstrom (1958)	$V_{max} = k(Q/D^{2/3})^{b/2}$
Duvall and Petkof (1959)	$V_{max} = k(D/Q^{1/2})^{-b}$
Devine et al (1963)	$V_{max} = k(D/Q^{1/2})^{-b}$
Ambraseys & Hendron (1968)	$V_{max} = k(D/Q^{1/3})^{-b}$
Nicholls et al. (1971)	$V_{max} = k(Q^a D^b)$
CMRI (1993)	$V_{max} = n + k(D/Q^{1/2})^{-1}$
Ramulu (2004)	$V_{max} = V(2(Bd/Bo)^{1/2} - 1)$
Kumar et al. (2016)	$V_{max} = ((0.3396 \text{ X } 1.02^{GSI}\ GSI^{1.13})^{0.642} D^{1.463})/r$
Kumar et al. (2016)	$V_{max} = ((0.5947RQD+0.00893RQD^2)^{0.642} D^{1.463})/r$ ($RQD \leq 75$)
Kumar et al. (2016)	$V_{max} = ((-7.9156RQD+0.1215RQD^2)^{0.642} D^{1.463})/r$ ($RQD > 75$)
Yin Z et al (2018)	$V_{max} = k\{[1+\log(1+JF(i).R(i))]SD\}-n$

Where,
V_{max}= magnitude of ground vibration, Q = maximum charge weight in any delay interval, D = distance from the blasting, K, a, b = constants whose values depend on the condition of site,
V=Vibration due to optimum burden, Bd= Deviated burden, Bo = Optimum burden, GSI = geological strength index, RQD= Rock quality designation
Effect of geological and mechanical properties of rock on blast-induced ground vibration studied by Ranjan et al. (2016). They collected published blast induced vibration data from various sources and used to propose a new empirical model equation. In their model they considered unit weight, rock quality designation (RQD), geological strength index (GSI), and uniaxial compressive strength (UCS). But in some cases RQD is zero, so GSI factor is considered as major element. They also compared their predicted results with others and stated that their model given much more good results. This study not investigated about effect of engineering rock properties on PPV. Iramina et al (2018) compared a Brazilian mine blast vibration by using ANN, empirical models and geo mechanical relationship models. In this research, they find ANN has good results compared with others.

II. EFFECT OF ROCK MASS PROPERTIES ON BLAST VIBRATIONS

Nicholls et al. (1971) concluded amplitude level of ground vibration is affected by geology and rock stratification, and its level is decreasing with the distance.Later Burkle (1979) research also concluded that different parameters rocks and geology of the location may affect the particle vibration. The particle velocity levels in soil surface and soil-rock surface investigated by Wu et al., 2003. Various studies (Hao et al.,2001; Ashford et al.2004&2006; Ak H Iphar and Konuk,2008; Kuzu 2008; and UFC 3-340-02,2008) investigated regarding the effect of rock joints, rock discontinues, joints thickness, joint set and joint numbers. Structural discontinuities study may helpful to find relationship between geology and vibration levels. Adhikari et al. (1999). The influences of joints on wave propagation direction, amplitude levels examined by Gong et al (2005,2006). Nateghi (2011) presented that particle displacement is more sensitive than velocity, while change in geological condition. The major and minor discontinuities also effect blast induced vibrations (Dindarloo et al., 2015).
Many researchers examined the rock properties effects on the peak particle velocity. The Indian standard institute studied about PPV in different rock units. They stated that site constants are different for different rock units, it proves that site constants and particle velocity significantly influenced by different rock properties. Later this supported by many investigators (ISRM ,1992; Adhikari et al. ,1999; Mohamed 2009; Alipour et al.,2012; Ranjan et al.,2016). Rock mass properties and density influences studied by ISRM (1992) in different rock units.
Adhikari et al. (1999) presented the effect of rock strength onsite constants and PPV. The investigators monitored many blasts in different mining and civil engineering project sites. They concluded that rock density and strength parameter relation with site constants is so weak. But increasing in the rock strength will increases the PPV level. The correlation is better with compressive strength and more pronounced at greater scaled distances. Consideration of rock properties may give a better model to predict the PPV. Chakraborty et al. (1998) and focused on the strength of the rock on the blast wave propagation. Görgülü et al. (2014) stated that rocks compressive strength significantly effects the particle displacement as well as velocity also.
Khandelwal and Singh (2006, 2009) studied in their ANN research about P-wave velocity Young's modulus, and Poisson's ratio relation with PPV. Many other AI models proposers (Mohamed ,2009; M. Monjezi et al.,2011; Hajihassani et al.,2014; Amiri et al.,2016) commented that incorporation of rock parameters is giving better results. Many developed AI models like ANN had rock strength, young modulus and etc as input parameters. Ozer (2008) and Mesec et al. (2010) focusses the influence of geological strength index (GSI). Ranjan et al. (2016) and Iramina et al (2018) incorporated RQD, GSI and uniaxial compressive strength in their model and presented that they had good correlation compared with other empirical models. This study concludes that mechanical and geological properties effecting ground vibration levels. Table-2 summarizes about studies investigated about different rock properties influencing the intensity of PPV.
The correlation between rock strength and PPV analysed by using Python programming tool. For this analysis blast vibrations are recorded various mines and civil projects. Rock strength determined through laboratory and field methods.

The major reason to choose Python

1. This software technique is very flexible to use. It is majorly deal with larger amount of data sets.
2. Python versions are free to use, so that any field engineer can use it.
3. It is well supported with windows and max

III. EFFECT OF ROCK PROPERTIES ON PPV:

The rock strength properties like compressive strength and tensile strength of different blasting locations correlated with PPV at different distances.
The correlation results are as follows

1. PPV is increasing with increasing the value of compressive strength of rocks. It is higher at 50m distance compared with 100m distance. The graph between PPV and Compressive strength at 50&100 scaled distances in figure-1 and figure-2. In both figures, compressive strength is constant but distance in figure-1 is 50m and in figure-2 is 100m.

These graphs concluding that at 50m distances PPV has good correlation with compressive strength compared to that of 100m. The R square decreasing from 0.67 to 0.50.

2. PPV is increasing with increasing the value of tensile strength of rocks. It is higher at 50m distance compared with 100m distance. The graph between PPV and tensile strength at 50&100 scaled distances in figure-3 and figure-4 In both figures, compressive strength is constant but distance in figure-3 is 50m and in figure-4 is 100m. These graphs concluding that at 100m distances PPV has good correlation with compressive strength compared to that of 100m. The R square increasing from 0.45 to 0.54.
3. The correlation between all factors (Compressive strength and Tensile strength,) presented in Figure-5. It clears that the influence of rock properties on PPV is very effective.

Table 2. Summary of the Effecting Rock Parameters on PPV mentioned by various researchers

S. N o	Reference	Rock Strength interfac e with soil or other rock	Rock Elastic Properties (Young Modulus,P -wave ,S-wave and etc)	Dynamic Rock Propertie s (GSI,RQ D and etc)
1	Adhikari et al. (1999)	✓		✓
2	Ak H, Konuk A. (2008)			
3	Aldaş GGU (2002)			✓
4	Alipour et al. (2012).	✓		✓
5	Ambrasey(1996)		✓	
6	Burkle, W.C., 1979		✓	
7	Chakraborty et al. (1998)	✓		
8	Chen and Huang (2001)		✓	
9	Dindarloo et al., 2015	✓		
10	Görgülü et al. (2014)	✓	✓	
11	Hao et al. (2001)	✓		
12	ISRM (1992)	✓		
13	IS 6922 (1973)	✓		
14	Kamalı and Ataei (2010)	✓		
15	Kamalı M et al. (2010)		✓	
16	Khandelwal & Singh (2011)		✓	
17	Kusumi et al., (2005)	✓		
18	Kuzmenko (1993)	✓		✓
19	Mohamed (2009)		✓	
20	Mesec et al. (2010)		✓	✓
21	Monjezi et al.(2011)			✓
22	Nateghi (2011)		✓	
23	Ozer (2008)		✓	✓
24	Ranjan et al. (2016).	✓		✓
25	Sambuelli (2009)	✓		
26	Singh et al. (2008)		✓	
27	UFC , 2008	✓		
28	Wu et al., 2003	✓		

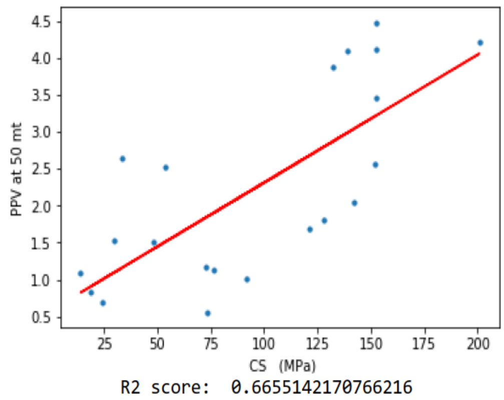

Figure-1: Comparison between PPV and Compressive strength at 50 and scaled distances

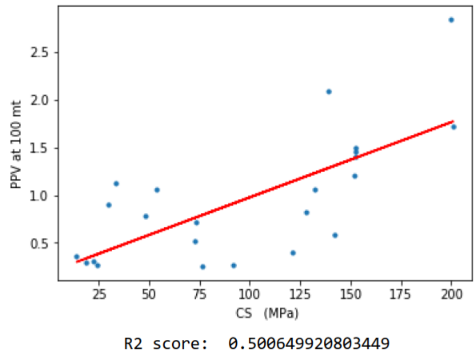

Figure-2: Comparison between PPV and Compressive strength at 100 and scaled distances

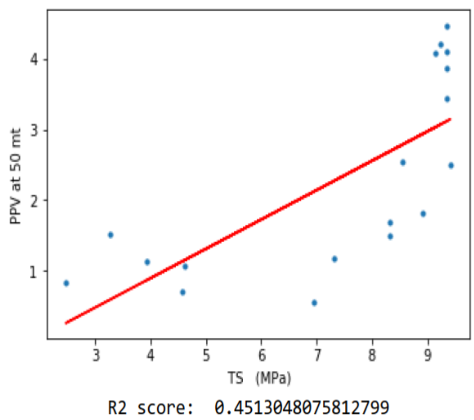

Figure-3. Comparison between PPV and Tensile strength at 50 and scaled distances

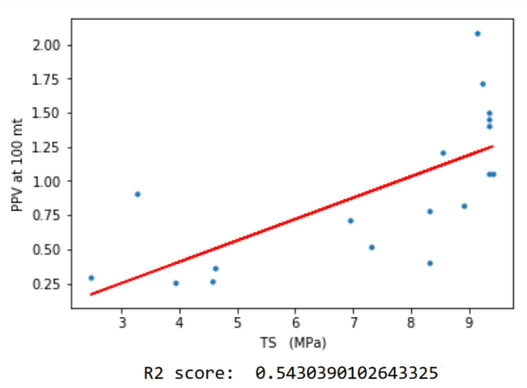

Figure-4. Comparison between PPV and Tensile strength at 100 and scaled distances

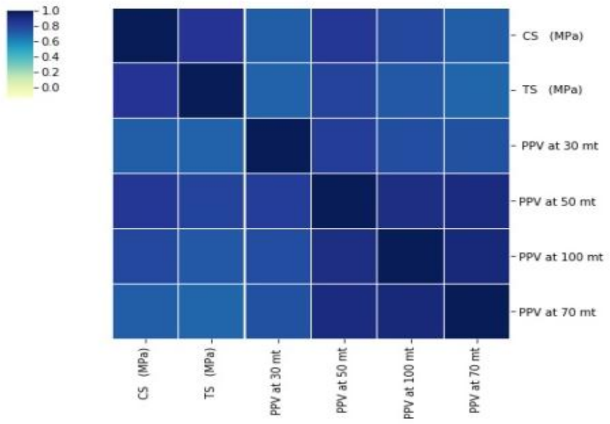

Figure-5. Correation matrix between PPV and Rock Stentgh at 30,50,70&100 distances

IV. CONCLUSION:

In this research, rock strength properties compared with PPV and following conclusion can be drawn from this study:

1. Peak particle velocity increases with an increase in compressive strength of the rocks .The correlation is better with compressive strength at 50 meter scale distance when compare with 100 meter scale distance.
2. Peak particle velocity increases with an increase in Tensile strength of the rocks .The correlation is better with tensile strength at 100-meter scale distance.
3. The relationship between peak particle velocity and rock properties such as compressive and tensile strengths is more pronounced at near field distances.

In this study, effect of dynamic properties such as p-wave and etc on PPV is not included. In future studies influence of dynamic properties on PPV will be studied.

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