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Controlling of the Environmental Effects of Air Shock Wave Due to Blasting In Quarry Mines

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Abstract

This paper presents controlling of the environmental effects of air shock wave due to blasting in quarry mines. The aim of this study is to predict the air overpressure due to blasting, in order to protect the dwelling area adjacent to the quarry. Prediction of air overpressure is important for mine operators who utilize blasting to ensure their blasts will not cause damage to nearby structures and stay within regulatory limits. Airblast is dependent on the size of the blast and air shock wave magnitude is dependent on how far away from the blast a recording device is located. Air shock waves are an integral part of the process of rock blasting and consequently they are unavoidable**.** In this paper, important and widely used empirical formulae have been used to predict the air over pressure for quarry mines. Moreover, a comparative analysis between the results obtained for constant charge per delay of 100 kg, and monitoring distance of 20 m, 30 m and 40 m were carried out to select the suitable empirical formula. The paper concludes with the guidelines for applying the air overpressure wave based on the various distances and amount of charges per delay.

Key Words: *Controlling, Air Shock Wave, Quarry Mines, Predict, Empirical Formulae, Comparative Analysis.*

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1. INTRODUCTION

Blasting is widely used in quarry mines. When explosive charges detonate in rock, most of the energy is used in breaking and displacing the rockmass. However, some of energy is released in the form of ground vibration and air-overpressure.

Blasting operations may cause excessive environmental impacts such as ground vibration, air shock wave, dust, and flyrock. Because blasting operations often focus on controlling fragmentation while neglecting the environmental consequences. Air shock wave is one of the undesirable effects and that occurs with the blasting. Air shock wave resulting from blasting can cause damage and nuisance to nearby civilians. Thus, it is important to be able to predict air shock wave accurately.

Air shock wave is a pressure wave and is also known as air vibrations, air overpressure or airborne shockwave. Air shock wave effects will always accompany blasting of rock, and will never be eliminated. The most important parameters to estimate the level of air shock wave are the amount of charge per delay and the distance to the measuring station. Moreover, the stemming length is also an important parameter.

In this study, empirical formulas and excel program are used to predict the level of air shock wave for quarry mines. The air shock wave damage and annoyance may be influenced by numerous factors such as blast design, weather, field characteristics, and human response.

2. METHODOLOGY

In order to meet the study objectives, firstly, Literature reviews were carried out to estimate the level of air over pressure. Secondly, important and widely used empirical formulae analysis were carried out to select the optimum empirical equation by using the excel program. Finally, predictions of air overpressure level were carried out with the various distances and amount of explosive (charge per delay) to control the blasting impact (air over pressure).

Several empirical predictors have been proposed by various scholars to estimate air shock wave level, but these methods are inapplicable in many conditions. In this paper, the following empirical formulas are used to predict the air shock wave level for quarry mines. Table 1 shows different empirical equations and site constants.

Table 1. Different empirical equations and site constants

References	Equations	H	B
Siskind et al. (1980) [2]	$AOp = H(DW^{-0.33})^{-B}$ (pascal)	622	0.515
United States Bureau of Mines USBM RI 8485 (1980) [1]	$AOp = H(DW^{-0.33})^{-B}$ (psi)	1.32	0.97
National Association of Australian State Road Authorities, NAASRA (1983) [6]	$AOp = (140 \times (W/200)^{0.33})/D$ (kpa)	-	-
Hajihassani et al. [7]	$AOp = H(DW^{-0.33})^{-B}$ (pascal)	10,909.000	1.09
Atlas Powder (1987) [4]	$AOp = H(W^{0.33}/D)^{-B}$ (kpa)	3.3	1.2
Persson et al. (1994) [6]	$AOp = H(W^{0.33}/D)$ (mbar)	0.7	1
Kuzu et al. (2009) [2]	$AOp = H(DW^{-0.33})^{-B}$ (pascal)	261.54	0.706

Where, AOp is air overpressure, H and B are site factors. D is the distance (m or ft), W is the charge weight per delay (kg or lb).

3. THE EFFECTS OF AIR OVERPRESSURE DUE TO BLASTING

The relationship of decibels to pressure and probable result of various airblast intensities are presented in table 2. The equivalent wind gust velocities are also given for several intensities.

Table 2. Result of various airblast intensities [3]

Airblast Intensity		Probable Result	Average Human Response
dB	Psi		
180	2.900	Structural damage	Ear drum rupture possible
175	1.631		
170	0.917	Many windows break	Intolerable
165	0.516		
160	0.290		
155	0.163	Equal to a 96 mph wind gust	
150	0.092	Poorly mounted windows can break	
145	0.052		
140	0.029	Equal to a 40 mph wind gust	Distinctly unpleasant
135	0.0145	OSMRE and USBM limit	
130	0.0092	Equal to a 23 mph wind gust	
125	0.0052		
120	0.0029		Mildly unpleasant
115	0.0016		
110	0.00092		
105	0.00052		
100	0.00029	Equal to a 7.2 mph wind gust	
95	0.00016		
90	0.000092		Strongly Perceptible
85	0.000052		
80	0.000029		
75	0.000016		
70	0.0000092		Distinctly Perceptible
65	0.0000052		
60	0.0000029		Perceptible

4. ANALYSIS OF EMPIRICAL FORMULA

In this paper, a comparative analysis between the results obtained with constant charge per delay of 100 kg and monitoring distance of 20m, 30m and 40m were carried out by using the various empirical formulas and excel program to select the suitable empirical formula for quarry mines. Figures 1 to 7 show the results of air overpressure level of different formulas.

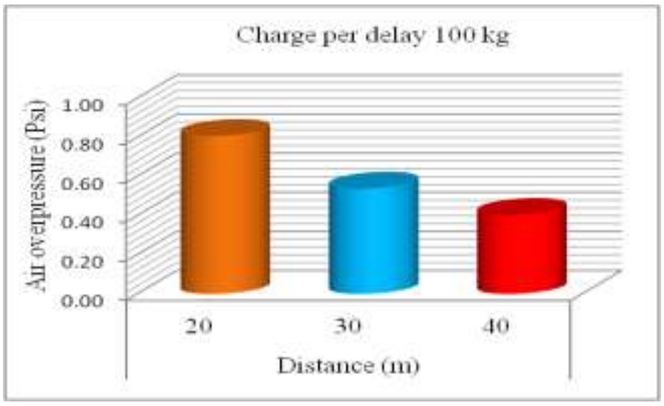

Figure 1. Air overpressure level of Siskind et al.

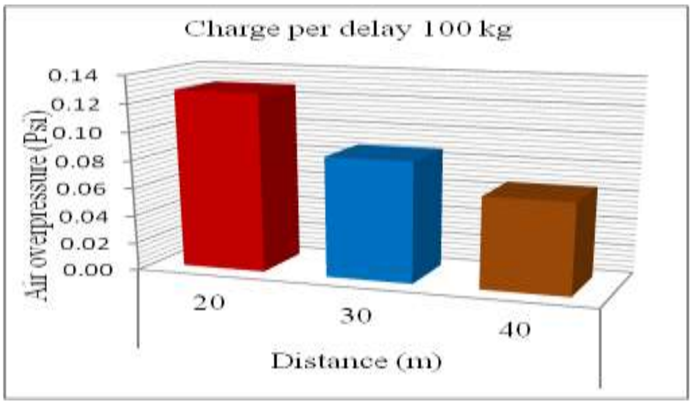

Figure 2. Air overpressure level of USBM method

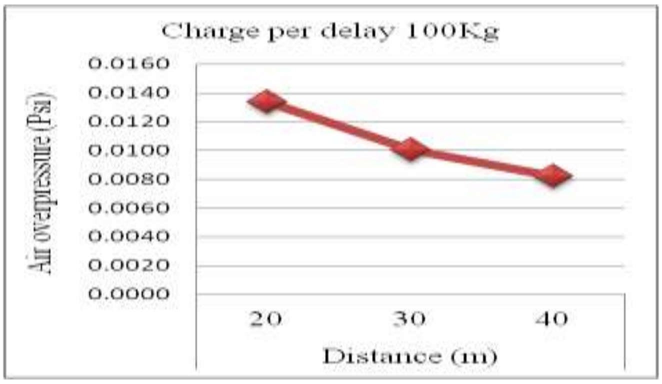

Figure 3. Air overpressure level of NAASRA method

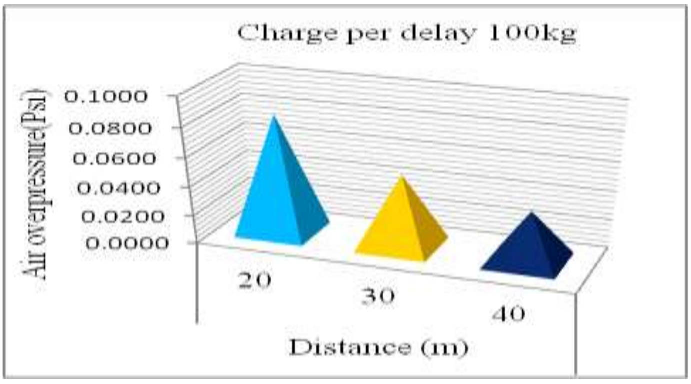

Figure 4. Air overpressure level of Hajihassani et al.

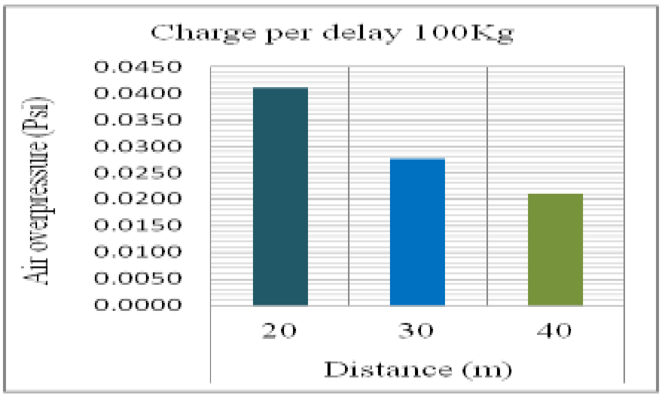

Figure 5. Air overpressure level of Atlas Powder

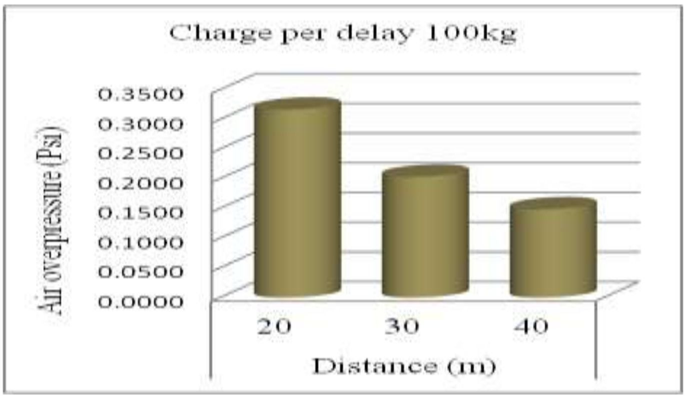

Figure 6. Air overpressure level of Persson et al.

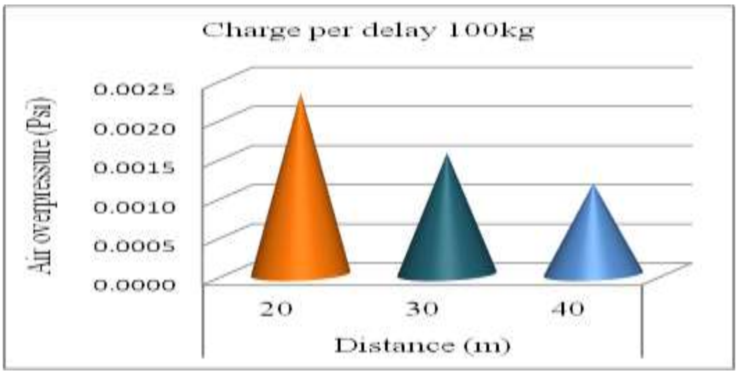

Figure 7. Air overpressure level of Kuzu et al.

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Figures 8 to 10 show the results of air overpressure for charge per delay 100 kg and distance 20m with the various empirical formulas. According to the figure 8, 9 and 10 results, National Association of Australian State Road Authorities, NAASRA (1983) method is the highest air overpressure level. Persson et al. (1994) method is the lowest air overpressure level. In this paper, the highest air overpressure (NAASRA method) is used to predict the maximum peak particle velocity for safety condition.

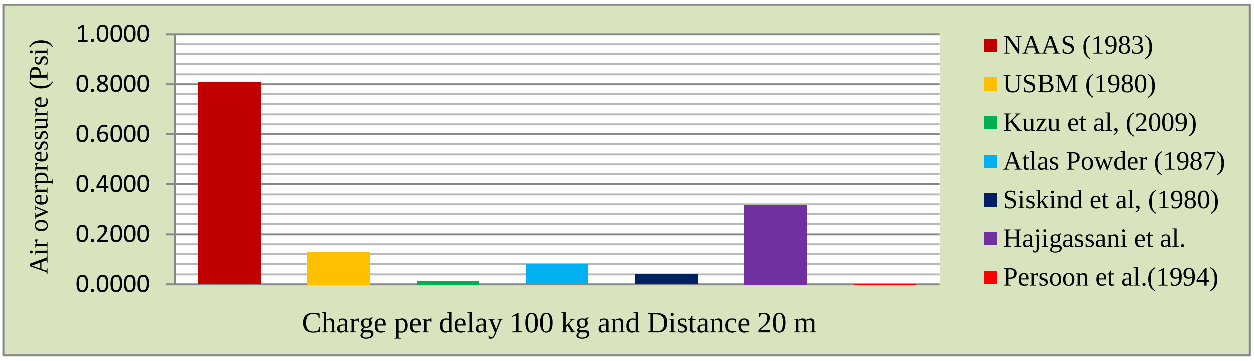

Figure 8. The results of air overpressure for charge per delay 100 kg and distance 20m

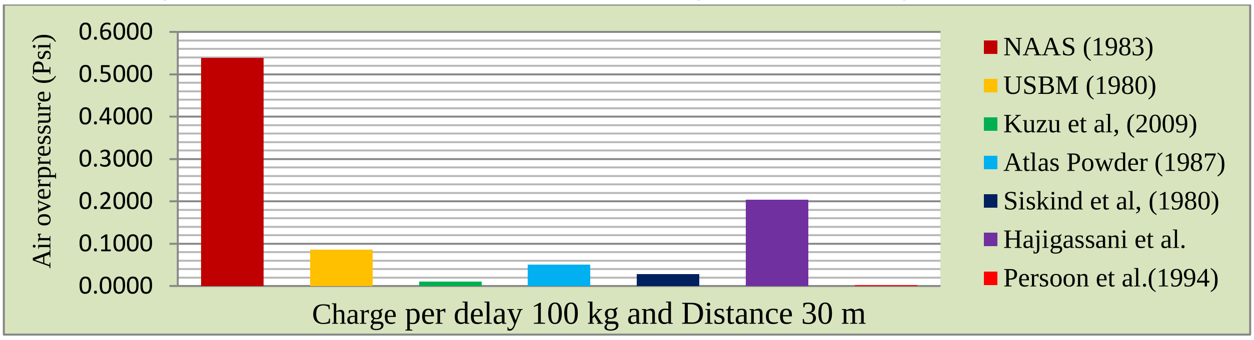

Figure 9. The results of air overpressure for charge per delay 100 kg and distance 30m

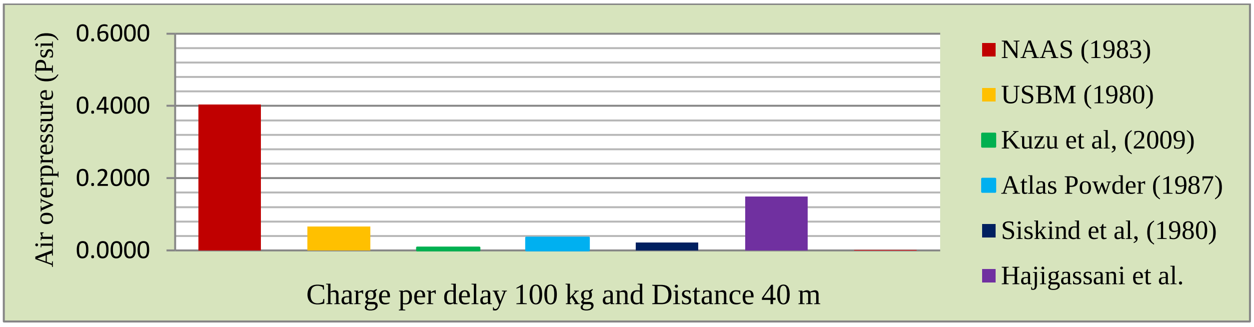

Figure 10. The results of air overpressure for charge per delay 100 kg and distance 40m

5. RESULTS AND DISCUSSION

In this paper, National Association of Australian State Road Authorities, NAASRA (1983) method is used to predict the air overpressure level for quarry mines. Table 3 to 8 show the results of air overpressure level with the various distance and charge per delay.

Table 3. The results of air overpressure (Psi) with the various distance and charge per delay (A)

Distance (m)	Charge per delay (kg)							
	25	50	75	100	125	150	175	200
20	0.511	0.642	0.734	0.807	0.869	0.923	0.971	1.015
30	0.341	0.428	0.490	0.538	0.579	0.615	0.647	0.677
40	0.255	0.321	0.367	0.404	0.435	0.462	0.486	0.507
50	0.204	0.257	0.294	0.323	0.348	0.369	0.388	0.406
60	0.170	0.214	0.245	0.269	0.290	0.308	0.324	0.338
70	0.146	0.184	0.210	0.231	0.248	0.264	0.277	0.290
80	0.128	0.161	0.184	0.202	0.217	0.231	0.243	0.254
90	0.114	0.143	0.163	0.179	0.193	0.205	0.216	0.226
100	0.102	0.128	0.147	0.161	0.174	0.185	0.194	0.203
110	0.093	0.117	0.134	0.147	0.158	0.168	0.177	0.185
120	0.085	0.107	0.122	0.135	0.145	0.154	0.162	0.169
130	0.079	0.099	0.113	0.124	0.134	0.142	0.149	0.156

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140	0.073	0.092	0.105	0.115	0.124	0.132	0.139	0.145
150	0.068	0.086	0.098	0.108	0.116	0.123	0.129	0.135
160	0.064	0.080	0.092	0.101	0.109	0.115	0.121	0.127
170	0.060	0.076	0.086	0.095	0.102	0.109	0.114	0.119
180	0.057	0.071	0.082	0.090	0.097	0.103	0.108	0.113
190	0.054	0.068	0.077	0.085	0.091	0.097	0.102	0.107
200	0.051	0.064	0.073	0.081	0.087	0.092	0.097	0.101

Table 4. The results of air overpressure (Psi) with the various distance and charge per delay (B)

Distance (m)	Charge per delay (kg)							
	225	250	275	300	325	350	375	400
20	1.055	1.092	1.127	1.160	1.191	1.221	1.249	1.276
30	0.703	0.728	0.752	0.773	0.794	0.814	0.833	0.851
40	0.528	0.546	0.564	0.580	0.596	0.610	0.624	0.638
50	0.422	0.437	0.451	0.464	0.477	0.488	0.500	0.510
60	0.352	0.364	0.376	0.387	0.397	0.407	0.416	0.425
70	0.301	0.312	0.322	0.331	0.340	0.349	0.357	0.365
80	0.264	0.273	0.282	0.290	0.298	0.305	0.312	0.319
90	0.234	0.243	0.251	0.258	0.265	0.271	0.278	0.284
100	0.211	0.218	0.225	0.232	0.238	0.244	0.250	0.255
110	0.192	0.199	0.205	0.211	0.217	0.222	0.227	0.232
120	0.176	0.182	0.188	0.193	0.199	0.203	0.208	0.213
130	0.162	0.168	0.173	0.178	0.183	0.188	0.192	0.196
140	0.151	0.156	0.161	0.166	0.170	0.174	0.178	0.182
150	0.141	0.146	0.150	0.155	0.159	0.163	0.167	0.170
160	0.132	0.137	0.141	0.145	0.149	0.153	0.156	0.159
170	0.124	0.129	0.133	0.136	0.140	0.144	0.147	0.150
180	0.117	0.121	0.125	0.129	0.132	0.136	0.139	0.142
190	0.111	0.115	0.119	0.122	0.125	0.129	0.131	0.134
200	0.106	0.109	0.113	0.116	0.119	0.122	0.125	0.128

Table 5. The results of air overpressure (Psi) with the various distance and charge per delay (C)

Distance (m)	Charge per delay (kg)							
	25	50	75	100	125	150	175	200
210	0.049	0.061	0.070	0.077	0.083	0.088	0.092	0.097
220	0.046	0.058	0.067	0.073	0.079	0.084	0.088	0.092
230	0.044	0.056	0.064	0.070	0.076	0.080	0.084	0.088
240	0.043	0.054	0.061	0.067	0.072	0.077	0.081	0.085
250	0.041	0.051	0.059	0.065	0.070	0.074	0.078	0.081
260	0.039	0.049	0.056	0.062	0.067	0.071	0.075	0.078
270	0.038	0.048	0.054	0.060	0.064	0.068	0.072	0.075
280	0.036	0.046	0.052	0.058	0.062	0.066	0.069	0.072
290	0.035	0.044	0.051	0.056	0.060	0.064	0.067	0.070
300	0.034	0.043	0.049	0.054	0.058	0.062	0.065	0.068
310	0.033	0.041	0.047	0.052	0.056	0.060	0.063	0.065
320	0.032	0.040	0.046	0.050	0.054	0.058	0.061	0.063
330	0.031	0.039	0.045	0.049	0.053	0.056	0.059	0.062
340	0.030	0.038	0.043	0.047	0.051	0.054	0.057	0.060
350	0.029	0.037	0.042	0.046	0.050	0.053	0.055	0.058
360	0.028	0.036	0.041	0.045	0.048	0.051	0.054	0.056
370	0.028	0.035	0.040	0.044	0.047	0.050	0.052	0.055
380	0.027	0.034	0.039	0.042	0.046	0.049	0.051	0.053
390	0.026	0.033	0.038	0.041	0.045	0.047	0.050	0.052
400	0.026	0.032	0.037	0.040	0.043	0.046	0.049	0.051

Table 6. The results of air overpressure (Psi) with the various distance and charge per delay (D)

Distance (m)	Charge per delay (kg)							
	225	250	275	300	325	350	375	400
210	0.100	0.104	0.107	0.110	0.113	0.116	0.119	0.122
220	0.096	0.099	0.102	0.105	0.108	0.111	0.114	0.116

DOI: 10.31695/IJASRE.2019.33575

230	0.092	0.095	0.098	0.101	0.104	0.106	0.109	0.111
240	0.088	0.091	0.094	0.097	0.099	0.102	0.104	0.106
250	0.084	0.087	0.090	0.093	0.095	0.098	0.100	0.102
260	0.081	0.084	0.087	0.089	0.092	0.094	0.096	0.098
270	0.078	0.081	0.084	0.086	0.088	0.090	0.093	0.095
280	0.075	0.078	0.081	0.083	0.085	0.087	0.089	0.091
290	0.073	0.075	0.078	0.080	0.082	0.084	0.086	0.088
300	0.070	0.073	0.075	0.077	0.079	0.081	0.083	0.085
310	0.068	0.070	0.073	0.075	0.077	0.079	0.081	0.082
320	0.066	0.068	0.070	0.073	0.074	0.076	0.078	0.080
330	0.064	0.066	0.068	0.070	0.072	0.074	0.076	0.077
340	0.062	0.064	0.066	0.068	0.070	0.072	0.073	0.075
350	0.060	0.062	0.064	0.066	0.068	0.070	0.071	0.073
360	0.059	0.061	0.063	0.064	0.066	0.068	0.069	0.071
370	0.057	0.059	0.061	0.063	0.064	0.066	0.068	0.069
380	0.056	0.057	0.059	0.061	0.063	0.064	0.066	0.067
390	0.054	0.056	0.058	0.059	0.061	0.063	0.064	0.065
400	0.053	0.055	0.056	0.058	0.060	0.061	0.062	0.064

Table 7. The results of air overpressure (Psi) with the various distance and charge per delay (E)

Distance (m)	Charge per delay (kg)							
	25	50	75	100	125	150	175	200
410	0.025	0.031	0.036	0.039	0.042	0.045	0.047	0.050
420	0.024	0.031	0.035	0.038	0.041	0.044	0.046	0.048
430	0.024	0.030	0.034	0.038	0.040	0.043	0.045	0.047
440	0.023	0.029	0.033	0.037	0.040	0.042	0.044	0.046
450	0.023	0.029	0.033	0.036	0.039	0.041	0.043	0.045
460	0.022	0.028	0.032	0.035	0.038	0.040	0.042	0.044
470	0.022	0.027	0.031	0.034	0.037	0.039	0.041	0.043
480	0.021	0.027	0.031	0.034	0.036	0.038	0.040	0.042
490	0.021	0.026	0.030	0.033	0.035	0.038	0.040	0.041
500	0.020	0.026	0.029	0.032	0.035	0.037	0.039	0.041
510	0.020	0.025	0.029	0.032	0.034	0.036	0.038	0.040
520	0.020	0.025	0.028	0.031	0.033	0.036	0.037	0.039
530	0.019	0.024	0.028	0.030	0.033	0.035	0.037	0.038
540	0.019	0.024	0.027	0.030	0.032	0.034	0.036	0.038
550	0.019	0.023	0.027	0.029	0.032	0.034	0.035	0.037
560	0.018	0.023	0.026	0.029	0.031	0.033	0.035	0.036
570	0.018	0.023	0.026	0.028	0.030	0.032	0.034	0.036
580	0.018	0.022	0.025	0.028	0.030	0.032	0.033	0.035
590	0.017	0.022	0.025	0.027	0.029	0.031	0.033	0.034
600	0.017	0.021	0.024	0.027	0.029	0.031	0.032	0.034

Table 8. The results of air overpressure (Psi) with the various distance and charge per delay (F)

Distance (m)	Charge per delay (kg)							
	225	250	275	300	325	350	375	400
410	0.051	0.053	0.055	0.057	0.058	0.060	0.061	0.062
420	0.050	0.052	0.054	0.055	0.057	0.058	0.059	0.061
430	0.049	0.051	0.052	0.054	0.055	0.057	0.058	0.059
440	0.048	0.050	0.051	0.053	0.054	0.055	0.057	0.058
450	0.047	0.049	0.050	0.052	0.053	0.054	0.056	0.057
460	0.046	0.047	0.049	0.050	0.052	0.053	0.054	0.055
470	0.045	0.046	0.048	0.049	0.051	0.052	0.053	0.054
480	0.044	0.046	0.047	0.048	0.050	0.051	0.052	0.053
490	0.043	0.045	0.046	0.047	0.049	0.050	0.051	0.052
500	0.042	0.044	0.045	0.046	0.048	0.049	0.050	0.051
510	0.041	0.043	0.044	0.045	0.047	0.048	0.049	0.050
520	0.041	0.042	0.043	0.045	0.046	0.047	0.048	0.049
530	0.040	0.041	0.043	0.044	0.045	0.046	0.047	0.048
540	0.039	0.040	0.042	0.043	0.044	0.045	0.046	0.047

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550	0.038	0.040	0.041	0.042	0.043	0.044	0.045	0.046
560	0.038	0.039	0.040	0.041	0.043	0.044	0.045	0.046
570	0.037	0.038	0.040	0.041	0.042	0.043	0.044	0.045
580	0.036	0.038	0.039	0.040	0.041	0.042	0.043	0.044
590	0.036	0.037	0.038	0.039	0.040	0.041	0.042	0.043
600	0.035	0.036	0.038	0.039	0.040	0.041	0.042	0.043

To obtain the values of air overpressure, it is necessary to find out values of site constants H and B. Site constants are main factors for prediction of air overpressure level due to blasting. Site constants can be determined by regression analysis. In this study, site constants are used directly from the book values. Generally high overpressure levels are caused due to inadequate stemming, mud or weak seam venting, inadequate burden confinement, poor blasting timing, focusing by wind or temperature inversions, uncovered detonation cord and overloading.

6. CONCLUSION

Blast-induced airblast or overpressure is one of the negative effects of blasting operations. The resulting noise usually generates a lot of uneasiness and irritation to neighbors giving rise to complaints. Blast-induced airblast can be minimized by properly designing and implementing blasts. The main cause of high frequency airblast tends to be holes blowing out, either by ejecting the stemming or by venting through mud seams. The expected air blast levels from blasting operations were calculated and considered in relation to the surrounding structures and installations.

To limit the air blast safe level, based on work carried out by Siskind *et.al.* (1980), monitored air blast amplitudes up to 135 dB are safe for structures, provided the monitoring instrument is sensitive to low frequencies (down to 1 Hz). [5] This paper focuses on the prediction of air overpressure level that is used for Myanmar quarry mines.

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