Assessment of Environmental Impact of Blasting within the Southern Extension Area at Jackdaw Crag Quarry, North Yorkshire

FCC ENVIRONMENT LIMITED

R22.11219/2/DW
Date of Report: 18 January 2022

REPORT DETAILS

Client	FCC Environment Limited
Report Title	Assessment of Environmental Impact of Blasting within the Southern Extension Area
Site Address	Jackdaw Crag Quarry, North Yorkshire
Report Ref.	R22.11219/2/DW
Vibrock Contact	vibrock@vibrock.com

QUALITY ASSURANCE

Issue No.	Issue Date	Comments	Author
1	18/11/21	n/a	Director
2	18/01/22	n/a	Director

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Vibrock Limited
Shanakiel
Ilkeston Road, Heanor
Derbyshire, DE75 7DR
Tel: +44 (0) 1773 711211
Fax: +44 (0) 1773 711311
Email: vibrock@vibrock.com
Web: www.vibrock.com

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1.0 INTRODUCTION

1.1 At the request of FCC Environment Limited Vibrock Limited were commissioned to undertake a blast induced vibration study for a proposal to permit blasting within the southern extension area at Jackdaw Crag Quarry.

2.0 ASSESSMENT SUMMARY

2.1 It is anticipated that the use of explosives to remove aggregate may be required to work the permitted lower working benches within the southern extension area at Jackdaw Crag Quarry.

2.2 Even the most well designed and executed of blasts generate a certain amount of energy in the form of both ground vibration and airborne vibration, therefore it has been considered prudent to undertake an assessment regarding the implications of quarry blasting within the permitted southern extension area at the site. The assessment was undertaken by Vibrock Limited, a national, independent firm of environmental consultants with a high level of expertise in this subject area.

2.3 The vibration predictions made by Vibrock Limited have been based upon an assumed blast design for the quarry and data from the monitoring of typical production blasts at quarries working similar strata. A review has also been undertaken of historic site monitored blast vibration data. Blast vibration records from the years 1996 to 2007 have been accessed.

2.4 The optimum blast design may vary from blast to blast and will necessarily be decided by the quarry operator with reference to the site specific conditions and in order to comply with the recommended vibration criteria. The assessment of the implications of blasting operations within Jackdaw Crag Quarry contains:

- The potential effect of blast induced vibration upon the occupants of residential property and National Grid Electricity and Gas infrastructure.
- Production of allowable instantaneous explosive charge weights for given separation distances.
- Recommendations for any mitigation / minimisation measures that should be adopted.

3.0 EFFECTS OF BLASTING

3.1 When an explosive detonates within a borehole stress waves are generated causing very localised distortion and cracking. Outside of this immediate vicinity, however, permanent deformation does not occur. Instead, the rapidly decaying stress waves cause the ground to exhibit elastic properties whereby the rock particles are returned to their original position following the passage of the stress waves. Such vibration is always generated even by the most well designed and executed of blasts and will radiate away from the blast site attenuating as distance increases.

3.2 With experience and knowledge of the factors which influence ground vibration, such as blast type and design, site geology and receiving structure, the magnitude and significance of these waves can be accurately predicted at any location.

3.3 Vibration is also generated within the atmosphere where the term air overpressure is used to encompass both its audible and sub-audible frequency components. Again, experience and knowledge of blast type and design enables prediction of levels and an assessment of their significance. In this instance, predictions can be made less certain by the fact that air overpressure levels may be significantly influenced by atmospheric conditions. Hence the most effective method of control is its minimisation at source.

3.4 It is important to realise that for any given blast it is very much in the operator’s interest to always reduce vibration, both ground and airborne to the minimum possible in that this substantially increases the efficiency and hence economy of blasting operations.

4.0 BLAST VIBRATION TERMINOLOGY

4.1 Ground Vibration

4.1.1 Vibration can be generated within the ground by a dynamic source of sufficient energy. It will be composed of various wave types of differing characteristics and significance collectively known as seismic waves.

4.1.2 These seismic waves will spread radially from the vibration source decaying rapidly as distance increases.

4.1.3 There are four interrelated parameters that may be used in order to define ground vibration magnitude at any location. These are:-

Displacement - the distance that a particle moves before returning to its original position, measured in millimetres (mm).

Velocity - the rate at which particle displacement changes, measured in millimetres per second (mms^{-1}).

Acceleration - the rate at which the particle velocity changes, measured in millimetres per second squared (mms^{-2}) or in terms of the acceleration due to the earth's gravity (g).

Frequency - the number of oscillations per second that a particle undergoes measured in Hertz (Hz).

4.1.4 Much investigation has been undertaken, both practical and theoretical, into the damage potential of blast induced ground vibration. Among the most eminent of such research authorities are the former United States Bureau of Mines (USBM), Langefors and Kihlström, and Edwards and Northwood. All have concluded that the vibration parameter best suited as a damage index is particle velocity.

4.1.5 Studies by the USBM have clearly shown the importance of adopting a monitoring approach that also includes frequency.

4.1.6 Thus the parameters most commonly used in assessing the significance of an impulsive vibration are those of particle velocity and frequency which are related for sinusoidal motion as follows:-

$$PV = 2 \pi f a$$

where PV = particle velocity
π = pi
f = frequency
a = amplitude

4.1.7 It is the maximum value of particle velocity in a vibration event, termed the peak particle velocity, that is of most significance and this will usually be measured in three independent, mutually perpendicular directions at any one location in order to ensure that the true peak value is captured. These directions are longitudinal (or radial), vertical and transverse.

4.1.8 Such maximum of any one plane of measurement is the accepted standard worldwide and as recommended by the British Standards Institution and the International Standards Organisation amongst others. It is also the basis for all the recognised investigations into satisfactory vibration levels with respect to damage of structures and human perception.

4.1.9 British Standard 7385 states that there is little probability of fatigue damage occurring in residential building structures due to blasting. The increase of the component stress levels due to imposed vibration is relatively nominal and the number of cycles applied at a repeated high level of vibration is relatively low. Non-structural components (such as plaster) should incur dynamic stresses which are typically well below, i.e. only 5% of, component yield and ultimate strengths.

4.2 Airborne Vibration

4.2.1 Whenever an explosive is detonated transient airborne pressure waves are generated.

4.2.2 As these waves pass a given position, the pressure of the air rises very rapidly to a value above the atmospheric or ambient pressure. It then falls more slowly to a value below atmospheric before returning to the ambient value after a series of oscillations. The maximum pressure above atmospheric is known as the peak air overpressure.

4.2.3 These pressure waves will comprise of energy over a wide frequency range. Energy above 20 Hz is perceptible to the human ear as sound, whilst that below 20 Hz is inaudible, however, it can be sensed in the form of concussion. The sound and concussion together is known as air overpressure which is measured in terms of decibels (dB) or pounds per square inch (p.s.i.) over the required frequency range.

4.2.4 The decibel scale expresses the logarithm of the ratio of a level (greater or less) relative to a given base value. In acoustics, this reference value is taken as 20×10^{-6} Pascals, which is accepted as the threshold of human hearing.

4.2.5 Air overpressure (AOP) is therefore defined as:-

$$\text{AOP, dB} = 20 \text{ Log } \frac{\text{(Measured pressure)}}{\text{(Reference pressure)}}$$

4.2.6 Since both high and low frequencies are of importance no frequency weighting network is applied, unlike in the case of noise measurement when an A - weighted filter is employed.

4.2.7 All frequency components, both audible and inaudible, can cause a structure to vibrate in a way which can be confused with the effects of ground vibrations.

4.2.8 The lower, inaudible, frequencies are much less attenuated by distance, buildings and natural barriers. Consequently, air overpressure effects at these frequencies can be significant over greater distances, and more readily excite a response within structures.

4.2.9 Should there be perceptible effects they are commonly due to the air overpressure inducing vibrations of a higher, audible frequency within a property and it is these secondary rattles of windows or crockery that can give rise to comment.

4.2.10 In a blast, airborne pressure waves are produced from five main sources:-

(i) Rock displacement from the face
(ii) Ground induced airborne vibration
(iii) Release of gases through natural fissures
(iv) Release of gases through stemming
(v) Insufficiently confined explosive charges

4.2.11 Meteorological factors over which an operator has no control can influence the intensity of air overpressure levels at any given location. Thus, wind speed and direction, temperature and humidity at various altitudes can have an effect upon air overpressure.

5.0 VIBRATION CRITERIA

5.1 Planning Practice Guidance to the National Planning Policy Framework (2014)

5.1.1 In March 2014 the Planning Practice Guidance was issued by the Government as a framework for assessing the environmental impacts of mineral extraction in England.

5.1.2 The guidance document states that the environmental impact of blasting operations should be assessed but does not provide an assessment framework or guidance on relevant planning conditions. The British Standards detailed within this report however provide relevant guidance which is in line with the vibration criteria detailed within the former Mineral Planning Guidance notes MPG 9 and 14, archived in March 2014.

5.1.3 The former MPG 9 and 14 stated that planning conditions should provide for limits on the timing of blasts and on ground vibrations received at sensitive properties, for monitoring to ensure that the limits are not exceeded and for methods to be employed minimising air overpressure.

5.1.4 Acceptable ground vibration criteria within the former MPG 9 and 14 suggested a range of between 6 to 10 mms^{-1} at a 95% confidence level measured at sensitive property, with no individual blast to exceed 12 mms^{-1}.

5.2 British Standard 6472–2: 2008 - Guide to evaluation of human exposure to vibration in buildings: Part 2: Blast-induced vibration

5.2.1 This document discusses how and where to measure blast-induced vibration and gives maximum satisfactory magnitudes of vibration with respect to human response. Satisfactory magnitudes are given as 6 to 10 mms^{-1} at a 90% confidence level as measured outside of a building on a well-founded hard surface as close to the building as possible.

5.2.2 Maximum satisfactory magnitudes of vibration with respect to human response for up to three blast vibration events per day are detailed within Table 1 of BS 6472-2: 2008:

Place	Time	Satisfactory magnitude[A)] (ppv mms^{-1})
Residential	Day [D)]	6.0 to 10.0 [C)]
	Night [D)]	2.0
	Other times [D)]	4.5
Offices [B)]	Any time	14.0
Workshops [B)]	Any time	14.0

A) The satisfactory magnitudes are the same for the working day and the rest day unless otherwise stated;
B) Critical working areas where delicate tasks impose more stringent criteria than human comfort are outside the scope of this standard;
C) With residential properties people exhibit a wide variation of tolerance to vibration. Specific values are dependent upon social and cultural factors, psychological attitudes and the expected degree of intrusion. In practice the lower satisfactory magnitude should be used with the higher magnitude being justified on a case-by-case basis;
D) For the purpose of blasting, daytime is considered to be 08h00 to 18h00 Monday to Friday and 08h00 to 13h00 Saturday. Routine blasting would not normally be considered on Sundays or Public Holidays. Other times cover the period outside of the working day but exclude night-time, which is defined as 23h00 to 07h00.

6.0 PREDICTION AND CONTROL OF VIBRATION LEVELS

6.1 Ground Vibration

6.1.1 The accepted method of predicting peak particle velocity for any given situation is to use a scaling approach utilising separation distances and instantaneous charge weights. This method allows the derivation of the site specific relationship between ground vibration level and separation distance from a blast.

6.1.2 A scaled distance value for any location may be calculated as follows:-

Scaled Distance,	SD	=	$DW^{-½}$ in $mkg^{-½}$
where	D	=	Separation distance (blast to receiver) in metres
	W	=	Maximum Instantaneous Charge (MIC) in kg i.e. maximum weight of explosive per delay interval in kg

6.1.3 For each measurement location the maximum peak particle velocity from either the longitudinal, vertical or transverse axis is plotted against its respective scaled distance value on logarithmic graph paper.

6.1.4 An empirical relationship derived by the United States Bureau of Mines (USBM) relates ground vibration level to scaled distance as follows:-

$$PV = a\,(SD)^{b}$$

where	PV	=	Maximum Peak Particle Velocity in mms^{-1}
	SD	=	Scaled Distance in $mkg^{-½}$
	a,b	=	Dimensionless Site Factors

6.1.5 The site factors a and b allow for the influence of local geology upon vibration attenuation as well as geometrical spreading. The values of a and b are derived for a specific site from least squares regression analysis of the logarithmic plot of peak particle velocity against scaled distance which results in the mathematical best fit straight line where

	a	is the peak particle velocity intercept at unity scaled distance
and	b	is the slope of the regression line

6.1.6 In almost all cases, a certain amount of data scatter will be evident, and as such statistical confidence levels are also calculated and plotted.

6.1.7 The statistical method adopted in assessing the vibration data is that used by Lucole and Dowding. The data is presented in the form of a graph showing the attenuation of ground vibration with scaled distance and results from log - normal modelling of the velocity distribution at any given scaled distance. The best fit or mean (50%) line as well as the upper 95% confidence level are plotted.

6.1.8 The process for calculating the best fit line is the least squares analysis method. The upper 95% confidence level is found by multiplying the mean line value by 1.645 times 10 raised to the power of the standard deviation of the data above the mean line. A log - normal distribution of vibration data will mean that the peak particle velocity at any scaled distance tends to group at lower values.

6.1.9 From the logarithmic plot of peak particle velocity against scaled distance, for any required vibration level it is possible to relate the maximum instantaneous charge and separation distance as follows:-

Maximum Instantaneous Charge (MIC) = $(D/SD)^2$

Where D	=	Separation distance (blast to receiver) in metres
SD	=	Scaled Distance in $mkg^{-½}$ corresponding to the vibration level required

6.1.10 The scaled distance approach assumes that blast design remains similar between those shots used to determine the scaling relationship between vibration level and separation distance and those for which prediction is required. For prediction purposes, the scaling relationship will be most accurate when calculations are derived from similar charge weight and distance values.

6.1.11 The main factors in blast design that can affect the scaling relationship are the maximum instantaneous charge weight, blast ratio, free face reflection, delay interval, initiation direction and blast geometry associated with burden, spacing, stemming and subdrill.

6.1.12 Although the instantaneous explosive charge weight has perhaps the greatest effect upon vibration level, it cannot be considered alone, and is connected to most aspects of blast design through the parameter blast ratio.

6.1.13 The blast ratio is a measure of the amount of work expected per unit of explosive, measured for example in tonnes of rock per kilogramme of explosive detonated (tonnes/kg), and results from virtually all aspects of a blast design, i.e. hole diameter, depth, burden, spacing, loading density and initiation technique.

6.1.14 The scaled distance approach is also strictly valid only for the specific geology in the direction monitored. This is evident when considering the main mechanisms which contribute to ground motion dissipation:-

- (i) Damping of ground vibrations, causing lower ground vibration frequencies with increasing distance.
- (ii) Discontinuities causing reflection, refraction and diffraction.
- (iii) Internal friction causing frequency dependent attenuation, which is greater for coarser grained rocks.
- (iv) Geometrical spreading.

6.1.15 In practice similar rates of vibration attenuation may occur in different directions, however, where necessary these factors should be routinely checked by monitoring, especially on sites where geology is known to alter.

6.1.16 Where it is predicted that the received levels of vibration will exceed the relevant criteria, the operator will have to reduce the maximum instantaneous explosive charge weight. One method of achieving such a reduction is to deck the explosives within the borehole. This technique splits the column of explosives in two, separated by inert material. If blasting is required at closer distances than that where double decking would be a successful strategy, other charge reduction methods would have to be employed. These could be more complex decking strategies or changes to the blast geometry and / or the use of smaller diameter boreholes.

6.2 Airborne Vibration

6.2.1 Airborne vibration waves can be considered as sound waves of a higher intensity and will, therefore, be transmitted through the atmosphere in a similar manner. Thus meteorological conditions such as wind speed, wind direction, temperature, humidity and cloud cover and how these vary with altitude, can affect the level of the air overpressure value experienced at a distance from any blast.

6.2.2 If a blast is fired in a motionless atmosphere in which the temperature remains constant with altitude then the air overpressure intensity will decrease purely as a function of distance. In fact, each time the distance doubles the air overpressure level will decrease by 6dB. However, such conditions are very rare and it is more likely that a combination of the factors mentioned above will increase the expected intensity in some areas and decrease it in others.

6.2.3 Given sufficient meteorological data it is possible to predict these increases or decreases. However, to be of use this data must be both site specific and of relevance to the proposed blasting time. In practice this is not possible because the data is obtained from meteorological stations at some distance from the blast site and necessarily at some time before the blast is to be detonated. The ever changing British weather therefore causes such data to be rather limited in value and its use clearly counter productive if it is not relevant to the blast site at the detonation time. In addition, it would not normally be safe practice to leave charged holes standing for an unknown period of time.

6.2.4 It is because of the variability of British weather that it is standard good practice to control air overpressure at source and hence minimise its magnitude at distance, even under relatively unfavourable conditions.

6.2.5 Such control is achieved in a well designed and executed blast in which all explosive material is adequately confined. Thus particular attention must be given to accurate face profiling and the subsequent drilling and correct placement of explosive within any borehole, having due regard to any localised weaknesses in the strata including overbreak from a previous shot, clay joints and fissured ground.

6.2.6 Stemming material should be of sufficient quantity and quality to adequately confine the explosives, and care should be taken in deciding upon the optimum detonation technique for the specific site circumstances.

6.2.7 Although there will always be a significant variation in observed air overpressure levels at a particular site it is possible to predict a range of likely values given sufficient background information and/or experience. In this respect, past recordings may be analysed according to the cube root scaled distance approach to provide a useful indication of future levels.

7.0 BLAST INDUCED VIBRATION MEASUREMENTS

7.1 Blast vibration data monitored at quarry sites working similar strata to that at Jackdaw Crag Quarry has been accessed from the Vibrock database.

7.2 The resulting regression line formed from this data has been used in order to be able to predict the anticipated future vibration levels at the various adjacent vibration sensitive locations and also to establish the likely allowable instantaneous charge weights when operations approach such features.

8.0 DISCUSSION

8.1 Interpretation of the regression curve has been undertaken for the vibration sensitive receptors listed in Tables 1 to 3 and Figure 1.

8.2 Table 1 gives the allowable instantaneous explosive charge weights in order to comply with the recommended site vibration criterion at residential property of 6 mms^{-1} at a 95% confidence level at the given separation distances.

8.3 The closest of residential properties to the mineral extraction area is Warren Cottage to the south of the working area and blasting activity.

8.4 Table 3 details the predicted vibration levels when blasting within the mineral extraction area and employing a typical maximum instantaneous explosive charge weight of 120 kg, at the nearest possible distance of approach to the locations given. The MIC will however be determined on a blast by blast basis with reference to the site specific conditions in order to comply with the recommended vibration criterion.

8.5 The predicted maximum vibration levels given will only occur when blasting at the nearest possible distance of approach to the respective locations.

8.6 As such, the vast majority of blasting events will be significantly below the levels given.

8.7 For each prediction, the mean (50%) value is the level which the regression analysis suggests is the most likely vibration level, with the maximum value being the upper 95% and 99.9% confidence levels from the regression analysis.

Warren Cottage

8.8 Warren Cottage is located immediately to the south of the mineral extraction area. Blasts should be designed with reference to Table 1, where a reduction in the charge weight would be necessary in order to comply with the recommended vibration criterion.

The Old School House

8.9 The Old School House is located to the south east of the mineral extraction area where a vibration level from the closest of blasting operations is predicted to be 0.6 mms^{-1} at a 95% confidence level.

8.10 The predicted vibration levels are within the recommended vibration criterion of 6 mms^{-1} at a 95% confidence level.

Sugar Hill Farm

8.11 Sugar Hill Farm is located to the east of the mineral extraction area. Considering the utilisation of instantaneous explosive charge weights of up to 120 kg, a vibration level from the closest of blasting operations of 0.5 mms^{-1} is predicted at a 95% confidence level.

8.12 The predicted vibration levels are within the recommended vibration criterion of 6 mms^{-1} at a 95% confidence level.

Redundant National Grid Gas Capped Pipeline

8.13 Discussions between National Grid Gas and FCC have been undertaken in relation to the redundant gas pipeline which will be terminated to the west of the site and filled with inert material.

8.14 Guidance from National Grid Gas has been received which requires a vibration criterion of 75 mms^{-1} to be applied at the capped dome end of the pipeline. The allowable maximum instantaneous explosive charge weights per separation distance to comply with the vibration criterion are presented in Table 2.

Electricity Pylon to the West of the Site

8.15 The closest electricity pylon to blasting activity within the southern extension area is located to the west of the site.

8.16 The maximum likely vibration level predicted at the pylon is 12.3 mms^{-1} at a 99.9% confidence level, within the usually applied National Grid criterion of 50 mms^{-1}.

Brick House Farm

8.17 Brick House Farm is located to the north of the A64. The closest of blasting operations within the southern extension area, when utilising a maximum instantaneous charge weight of 120 kg, is predicted to generate a vibration level of 0.7 mms^{-1} at a 95% confidence level.

8.18 The predicted vibration levels are well within the recommended vibration criterion of 6 mms^{-1} at a 95% confidence level.

9.0 CONCLUSIONS

9.1 A criterion for restricting vibration levels from production blasting has been recommended in order to address the need to minimise annoyance to nearby residents. Accordingly, Vibrock recommends the use of a vibration criterion of 6 mms^{-1} for 95% of events as a satisfactory magnitude for vibration from blasting at Jackdaw Crag Quarry.

9.2 The use of such a vibration criterion will be in accordance with relevant mineral planning and British Standard guidance and will result in a non-significant effect at adjacent residential and infrastructure elements.

9.3 All blasts at Jackdaw Crag Quarry shall be designed in order to comply to a vibration criterion of 6 mms^{-1} peak particle velocity at a 95% confidence level at residential property as measured in any of the three planes of measurement.

9.4 All vibration will be of a low order of magnitude and would be entirely safe with respect to the possibility of the most cosmetic of plaster cracks as detailed within British Standard 7385-2: 1993.

9.5 Vibration will also be within those levels recommended for blast induced vibration and human perception as being satisfactory within the previously discussed British Standard Guide BS 6472-2: 2008.

9.6 With such low ground vibration levels accompanying air overpressure would also be of a very low and hence safe level, although possibly perceptible on occasions at the closest of properties.

9.7 Allowable charge sizes have been derived/vibration levels predicted for the adjacent gas and electricity infrastructure to ensure compliance with the recommended vibration criteria.

10.0 RECOMMENDATIONS

10.1 The following recommendations are presented in order to minimise the vibration impact of blasting operations within the southern extension area at Jackdaw Crag Quarry at nearby residential receptors to ensure no unacceptable adverse effects are experienced.

Ground Vibration - Inhabited Property

10.2 We recommend that a ground vibration limit is chosen that not only is perfectly safe for the integrity of structures, but also takes into account the human perception effects on adjacent neighbours. As such we recommend a vibration limit of 6 mms^{-1} peak particle velocity at a 95% confidence level.

Air Overpressure

10.3 Our considerable past experience of air overpressure measurement and control leads us to the firm conclusion that it is totally impracticable to set a maximum air overpressure limit, with or without an appropriate percentile of exceedances being allowed, simply because of the significant and unpredictable effect of variable weather conditions. This point is recognised by the DETR publication The Environmental Effects of Production Blasting from Surface Mineral Workings and British Standard 6472-2: 2008.

10.4 With a sensible ground vibration limitation the economics of safe and efficient blasting will automatically ensure that air overpressures are kept to reasonable levels.

10.5 We therefore recommend that in line with the current best accepted modern practice in the extraction industries that safe and practical measures are adopted that ensure the minimisation of air overpressure generated by blasting at source, considering such factors as initiation technique.

Monitoring and Control

10.6 The mineral operator should design blasting operations taking into account the findings of this report.

10.7 It is recommended that the first blast within the permitted southern extension area be deemed a test blast from which a site specific regression line should be derived. A programme of blast monitoring should be conducted at adjacent receptors. The results of such monitoring should be used to update the initial regression line. The regression line should be interpreted so that for each blast the correct maximum instantaneous explosive charge weight for adjacent structures and services is utilised.

11.0 REFERENCES

1. BS ISO 4866: 2010. Mechanical vibration and shock – Vibration of fixed structures – Guidelines for the measurement of vibrations and evaluation of their effects on structures. British Standards Institution.

2. BS 6472-2: 2008. Guide to evaluation of human exposure to vibration in buildings, Part 2: Blast-induced vibration. British Standards Institution.

3. BS 7385: 1993 Evaluation and measurement for vibration in buildings: Part 2. Guide to damage levels from groundborne vibration. British Standards Institution.

4. BS 5228-2: 2009 + A1:2014, Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration.

5. National Planning Policy Framework, Ministry of Housing, Communities and Local Government, July 2021.

6. The Environmental Effects of Production Blasting from Surface Mineral Workings, Vibrock Report on behalf of the DETR, 1998.

TABLE 1

ALLOWABLE MAXIMUM INSTANTANEOUS EXPLOSIVE CHARGE WEIGHTS – INHABITED PROPERTY AT JACKDAW CRAG QUARRY

From the regression line the corresponding scaled distance value for a vibration criterion of 6 mms^{-1} at a 95% confidence level is 21.2 $mkg^{-½}$.

This gives rise to the following allowable maximum instantaneous charge weights at the given blast/receiver separation distances:-

Blast/Receiver Separation Distance (metres)	Allowable Maximum Instantaneous Charge Weight, kg to comply with 6 mms^{-1} at 95% confidence level
20	0.8
40	3.5
60	7.9
80	14.1
100	22.1
120	31.8
140	43.4
160	56.7
180	71.7
200	88.6
220	107.2
233	120.2
240	127.5
260	149.7
280	173.6
300	199.3

TABLE 2

ALLOWABLE MAXIMUM INSTANTANEOUS EXPLOSIVE CHARGE WEIGHTS – NATIONAL GRID GAS PIPELINE AT JACKDAW CRAG QUARRY

From the regression line the corresponding scaled distance value for a vibration criterion of 75 mms^{-1} at a 99.9% confidence level is 8.9 $mkg^{-½}$.

This gives rise to the following allowable maximum instantaneous charge weights at the given blast/receiver separation distances:-

Blast/Receiver Separation Distance (metres)	Allowable Maximum Instantaneous Charge Weight, kg to comply with 75 mms^{-1} at 99.9% confidence level
15	2.8
25	7.8
35	15.3
45	25.3
55	37.8
65	52.9
75	70.4
85	90.4
95	113.0
105	138.0

TABLE 3

PREDICTED VIBRATION LEVELS
SOUTHERN EXTENSION AREA AT JACKDAW CRAG QUARRY

Considering a maximum instantaneous charge weight of 120 kg utilised in the development area at the nearest distance of approach to the location considered, the predicted vibration levels are as follows:-

Location	Vibration Level Peak Particle Velocity (mms^{-1})		
	Confidence Level (50%)	Confidence Level (95%)	Confidence Level (99.9%)
1	3.4	6.0*	9.7
2	0.4	0.6	1.0
3	0.3	0.5	0.9
4	4.4	7.6	12.3
5	0.4	0.7	1.1
6	26	46	75*

* Maximum instantaneous explosive charge weights reduced in line with Table 1/2 in order to comply with vibration criterion.

Locations (see Figure 1)

1. Warren Cottage
2. The Old School House
3. Sugar Hill Farm
4. Electricity Pylon
5. Brick House Farm
6. Redundant National Grid Gas Capped Pipeline

FIGURE 1

PREDICTION LOCATIONS

1. Warren Cottage
2. The Old School House
3. Sugar Hill Farm
4. Electricity Pylon
5. Brick House Farm
6. Redundant National Grid Gas Capped Pipeline