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EPC GROUPE

BREEDON TRADING LIMITED

DENBIGH QUARRY

Proof of Evidence Relating to the Environmental Impact of Blasting

07/07/2025

CAS-03423-V9Z8M3

EPC GROUPE EPC-UK

Enabling mineral sustainability

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1 Qualifications and Experience

My name is Dr Robert Farnfield and I am a Consultant Explosives Engineer employed by EPC United Kingdom Ltd (EPC-UK). I hold a BSc (Hons) degree in Mining Engineering from the University of Leeds and a PhD relating to the Environmental Impact of Blasting Operations, also from the University of Leeds. I am a Fellow of the Institute of Quarrying and a Member of the International Society of Explosives Engineers.

I have been working in the field of the environmental impact of blasting operations for more than 30 years and have published more than 20 technical papers on the topic. I have also served on two British Standards committees covering vibration induced structural damage (BS7385 Part 2) and human response to vibration (BS6472).

My employer, EPC-UK, carries out drilling and blasting operations at Denbigh Quarry under contract to Breedon Trading Limited.

2 Declaration

The evidence which I have prepared and provide for this appeal is true to the best of my knowledge and I confirm that the opinions expressed are my true and professional opinions in the matters to which they refer.

3 Preamble

The extraction of rock from most quarries in the UK requires the use of explosives in order to fragment the rock sufficiently to enable safe and efficient extraction. Quarrying of the rock at Denbigh Quarry would not be possible without the use of explosives.

The environmental impact of blasting can be considered in four aspects as outlined in the following sections.

3.1 Ground Vibration

When explosives are detonated in a quarry blast hole, most of the generated energy is consumed in the process of fragmenting and moving the rock. The remaining energy moves away from the blast area as stress waves through the rock mass generating ground vibration. Such ground vibration will travel away from the blast area attenuating with distance at a rate depending on the geology of the area.

3.2 Air Overpressure

When a blast is initiated, the rock blasted will move away from the blast area to a distance of about two times the original face height, this movement results in a vibration wave being generated in the air generally known as air overpressure. The air overpressure will travel away from the blast area attenuating with distance at a rate depending on atmospheric conditions. Most of the energy in the air overpressure wave is sub-audible with only a limited amount being in the range audible to human beings.

3.3 Fly Rock

Fly rock is defined under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 and is defined as material from a blast being projected beyond the declared danger zone for that blast. Whilst such incidents are very rare the possibility of such an incident can be of concern for residents.

3.4 Dust

Dust can be generated during the drilling of blast holes and during the blast itself. All modern drilling equipment is provided with a means of capturing any dust generated in the drilling process. During the blast itself, the rock fragmentation and movement process inevitably results in the generation of some air borne dust. Dust can also be generated from the broken rock landing on the quarry floor as well as being liberated from the surface area of the blast.

4 Legislation, Relevant Guidance and Standards

4.1 Quarries Regulations 1999

The use of explosives in quarries is covered by the Quarries Regulations 1999. These regulations are primarily concerned with health and safety and as such have little impact on the control of the environmental impact of blasting operations other than where safety precautions have a coincidental impact on such impacts as is the case with fly rock and air overpressure.

4.2 Mineral Technical Advice Note (Wales) 1: Aggregates (MTAN1)

This document includes a part on the environmental impact of blasting under sections 78 to 84. In this document the impacts are listed as vibration and fly rock with the term vibration covering both vibration through the ground and vibration through the air (air overpressure).

4.2.1 *Ground Vibration*

MTAN1 notes that the level of ground vibration likely to generate complaints varies considerably from person to person and from site to site and quotes research that suggests that the level of complaint depends to a large degree on the relationship between the quarry operator and the local residents.

The document also notes that people are relatively sensitive to ground vibration and are likely to have a threshold of perception as low as 0.5 $mm.s^{-1}$. The document also notes that local residents are often concerned about the possibility of structural damage to their properties.

The topic of structural damage is addressed in MTAN1 by reference to the British Standard BS7385: Evaluation and Measurement for Vibrations in Buildings Part 2: 1993.

4.2.2 *Air Overpressure*

MTAN1 notes that because air overpressure is transmitted through the atmosphere, weather conditions have a controlling influence on the levels received at residential properties and that, in view of this unpredictability, planning conditions to control air overpressure are unlikely to be enforceable. It is however noted that blasts should be designed to minimise air overpressure levels and that such details are sufficiently covered by the requirements under the Quarries Regulation for blasting to be carried out safely.

4.2.3 *Fly Rock*

MTAN1 correctly notes that the control of fly rock is primarily a safety issue and is as such addressed by the Quarries Regulations 1999 and Approved Code of Practice and Guidance associated with these regulations. As such the control of the risk of fly rock is a standard part of the proper blast design process undertaken at all quarries in the UK. The use of appropriate technologies and design processes ensures that sufficient confinement of the explosives is assessed before the firing of any blast. A robust post-blast review process is also undertaken to address any potential issues that may have come to light during the loading and firing of each blast. The design, loading and firing of all blasts can only be undertaken by fully qualified and competent individuals.

Any fly rock incident is reportable under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013, no such incidents have been reported at Denbigh Quarry.

4.3 British Standard BS7385: Evaluation and Measurement for Vibrations in Buildings Part 2: 1993

This standard addresses the topic of structural damage from ground borne vibration including that from blasting. The guidance outlined in the standard was compiled from a wide-ranging review of research undertaken in this field of study.

The criteria recommended to predict the likelihood of structural damage is the Peak Particle Velocity (PPV) measured at foundation level. The standard details a lower bound for the possibility of structural damage via a PPV level that changes with the frequency of the ground vibration. The lowest possible PPV, irrespective of frequency, for cosmetic damage (minor cracks in plaster) is 15 $mm.s^{-1}$.

4.4 British Standard BS6472: Guide to the Evaluation of Human Exposure to Vibration in Buildings Part 2: Blast-Induced Vibration

This standard addresses the issue of the response of people in structures subject to blast induced ground vibration. Table 10.1 in this standard suggests a maximum satisfactory vibration level in residential properties of 6 to 10 $mm.s^{-1}$. As with BS7385, the recommended location for the vibration limit is at foundation level.

4.5 ISEE Blasters' Handbook

There are no standards for blast-induced air overpressure in the UK giving guidance on the levels likely to cause structural damage. The International Society of Explosives Engineers publishes the Blasters' Handbook, and this has recommendations relating to air overpressure quoting work carried out by the United States Bureau of Mines. The recommended limit in this case is 133 dB(Linear) or 89 Pascals (Pa).

Air overpressure levels are often quoted in terms of dB which relates the pressure level to the threshold of hearing on a logarithmic scale which can often be confusing.

5 Compliance of the Existing Operation with the Current Planning Conditions

5.1 Planning Conditions

Current conditions are specified in the certificate of decision, code number 01/2019/0757/PS and the associated condition 26 (shown in Appendix 1), approved under application number 01/2023/0239 dated 08/12/2023.

5.2 Peak Particle Velocity

As part of the current planning conditions, limits on permitted levels of ground vibration at the nearest residential or other vibration sensitive property affected by vibration from blasting are set such that when calculated with a 95% confidence limit, the Peak Particle Velocity (PPV), measured as a maximum of three mutually perpendicular directions, shall not exceed 6 $mm.s^{-1}$.

Also, as part of the permission, the quarry operator must monitor the vibration and air overpressure levels from each blast as detailed in an agreed monitoring scheme. The results of this monitoring are available for inspection by the local authority.

A limit is also placed on the number of individual blast events in a 12-month period which shall be no more than 12.

Figure 1 below shows a distribution of recent vibration monitoring data from February 2021 to May 2025. Each column represents the number of recorded measurements made in the corresponding PPV range. It can be seen that there are no recordings above 6 $mm.s^{-1}$ thus proving complete compliance with the planning conditions.

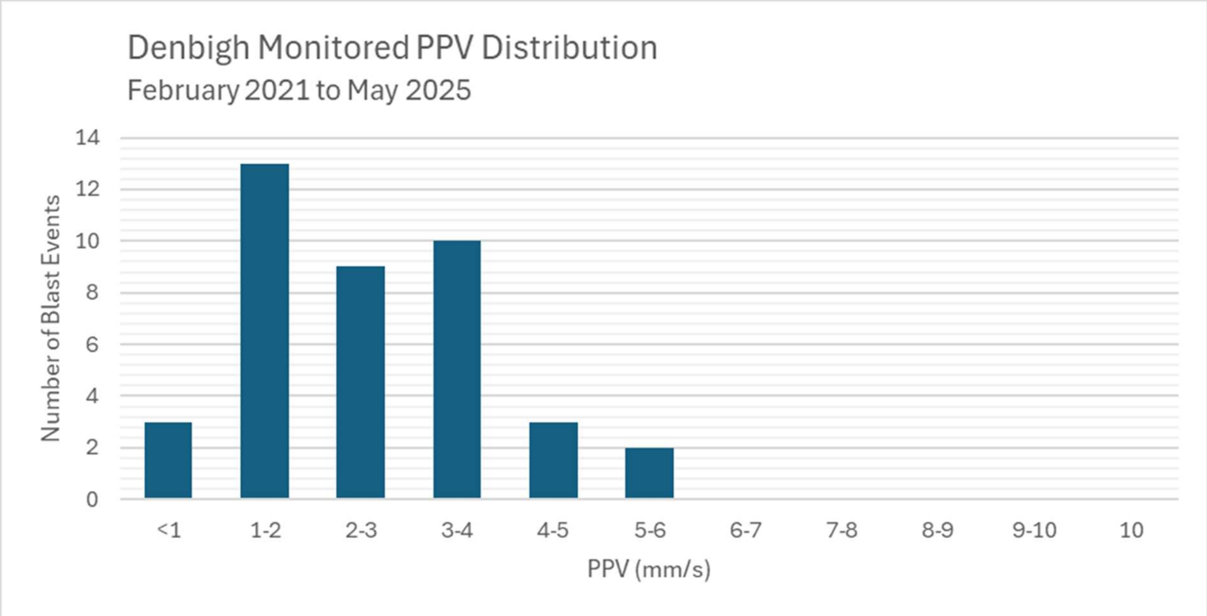

Figure 1 Distribution of PPV values at Denbigh Quarry over the period February 2021 to May 2025

5.3 Peak Air Overpressure

As part of the agreed monitoring scheme, Peak Air Overpressure readings are also taken and made available to the local authority on request.

No limit is specified in planning conditions on the peak air overpressure; however, it is stated that best practical means shall be employed at all times to minimise the air over-pressure from blasting operations. This is in line with guidance in MTAN1 due to the inherent unpredictability of air overpressure caused by varying atmospheric conditions.

Figure 2 below shows a distribution of the peak air overpressure (PAoP) recordings made in the period February 2021 to May 2025. Though no limit is specified for the site, all of the reading are beneath the ISEE recommended limit of 133 dB(L) as described in Section 4.5.

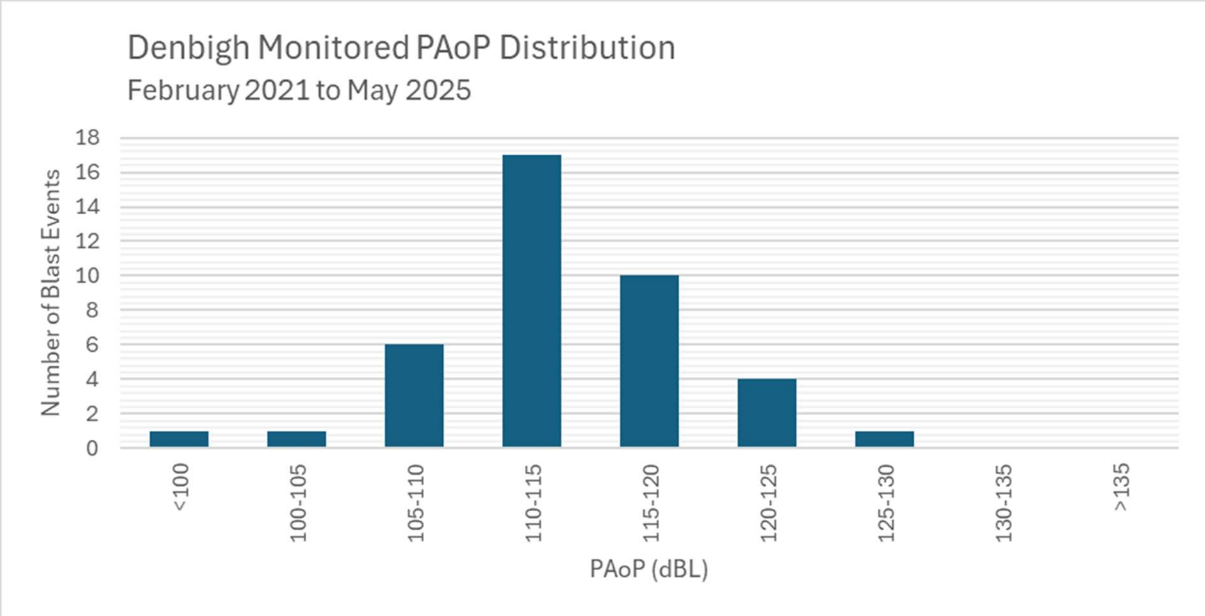

Figure 2 Distribution of PAoP values at Denbigh Quarry over the period February 2021 to May 2025

6 Environmental Control Strategies

6.1 Ground Vibration

Levels of ground vibration from blasting operations, as received at a location, are known to be related to the distance of the location from the blast and the maximum instantaneous charge weight (MIC) employed in the blast. These two parameters are combined to form a parameter known as scale distance as follows:

Scaled Distance = Distance / √ MIC

Using the calculated scaled distance values and corresponding vibration levels, a graph can be compiled relating scaled distance to vibration levels – often known as a regression line. The regression line itself represents the best fit relationship between the two parameters also known as the 50% confidence line as half of the data will be above the line and half below. An example regression line from Denbigh is shown in Figure 3.

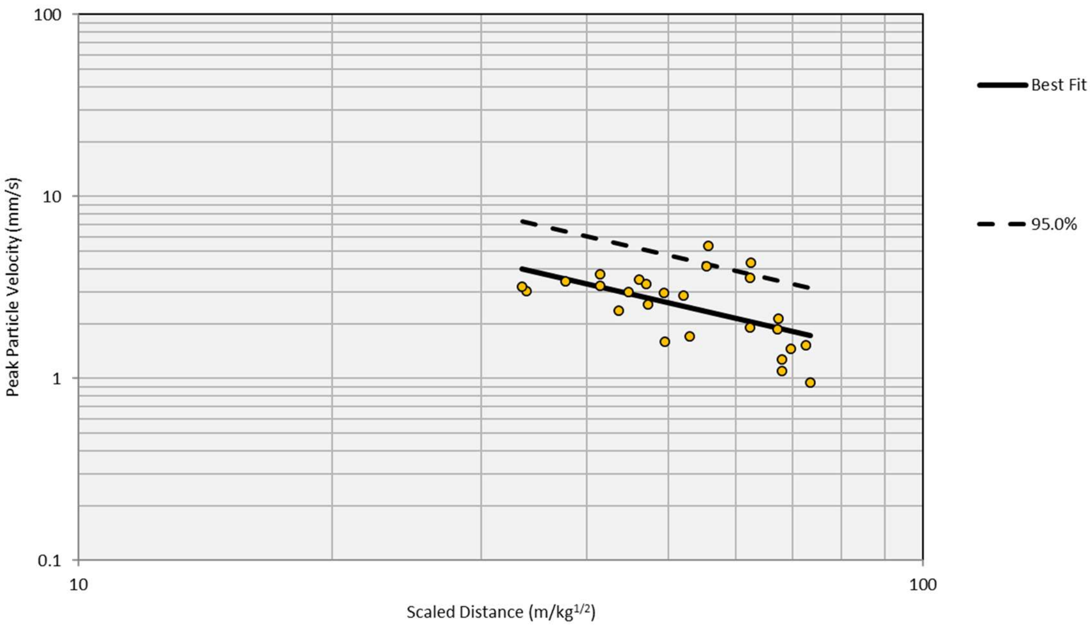

Figure 3 Example Regression Line Denbigh

The fact that only some of the data lies directly on the regression line simply reflects variability induced by factors such as geology. This scatter about the regression line can be used via classic statistics to generate additional lines with higher levels of confidence and this is typically done to match any planning condition – for Denbigh Quarry, the confidence level to match the current planning conditions would be 95% (shown on the example regression line as the dashed line).

6.1.1 Control by MIC

The MIC is taken to be the maximum mass of explosive fired at any single delay time. The primary method of control over vibration levels in quarry blasting is implemented by means of controlling the MIC value mainly using the technique known as decking. This technique is already employed at Denbigh Quarry and is the reason why vibration levels have been fully in compliance with the current planning conditions as shown previously in Figure 1.

The process employed determines the required MIC by reference to a site-specific regression line and using a combination of the 95% line and the required vibration line to determine a limiting scaled distance. Having determined a scaled distance value, the required MIC can be calculated from the distance to the nearest property.

This method of control is also known as ‘planning to comply’ and allows blasts to be designed to meet the planning permission irrespective of distance.

The limits of excavation given in the planning application for the extension of the workings require blasts to be carried out to within 250 m of existing properties and is considered to be both technically and economically feasible whilst keeping within the proposed planning conditions. This is inline with PSE 16 in the Denbighshire County Council Local Development Plan with regard to blasting which places a buffer zone of 200 m for hard rock mineral extraction.

6.2 Air Overpressure

The control of air overpressure levels is a relatively straight forward process as the techniques required are also those used to control the risk of fly rock as required by the Quarries Regulation 1999. The process of fly rock control, such as face profiling, blast hole surveying etc., will thus automatically minimise the levels of air overpressure.

Additional control measures outside of those required for the control of fly rock would include:

- The prohibition of exposed explosives charges for secondary breaking.
- Covering any surface connectors.
- Ensuring the delay times across a face are slower than 300 $m.s^{-1}$ to avoid the risk of matching the speed of sound.

6.3 Fly Rock

As previously noted, the control of fly rock is a standard part of any blast design process in the UK quarrying industry and is effectively controlled under the Quarries Regulations 1999.

6.4 Dust

Transient dust can be an issue from blasting operations due to the rock breaking process, the rapid movement of faces and the impact of the broken rock on the quarry floor. The most effective practical minimisation process is by damping down the area of the quarry on which blasted rock is expected to land.

7 Conclusions

Blasting operations at Denbigh Quarry have and can be controlled to comply with the limits recommended in MTAN1 relating to ground vibration and enforced via the planning conditions.

This is not to say that the levels of vibration currently experienced are not perceptible but that they are certainly well below those levels likely to cause even cosmetic damage.

Existing planning conditions requires the quarry to periodically update their planning to comply model database of blasting information along with the associated environmental monitoring results. This database can then be employed to design future blasts to comply with the planning condition via the use of the planning to comply technique previously described in Section 6.1.

The best practical means are employed at all times to minimise air over-pressure from blasting operations carried out on the site with values outlined in Figure 2 beneath the ISEE recommended limit of 133 dB(Linear).

Transient dust from blasting has clearly been an issue based on reviewed witness statements and it is recommended that this is addressed in the dust management plan.

The above controls support PSE 17 (f) in the Denbighshire County Council Local Development Plan to ensure that suitable blasting controls are implemented.

Dr R Farnfield – 07/07/2025

Appendix A. Condition 26 Blasting Impact Management Protocol

Please see over.

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03 April 2023

Blasting Impact Management Protocol at Denbigh Quarry, Breedon Trading Limited

This blasting impact management protocol set out between Breedon Trading Limited at Denbigh Quarry and EPC United Kingdom Limited (EPC-UK, blasting contractor) shall outline the methods and steps to be deployed to manage and mitigate against the environmental impact of blasting on-site.

Blasting shall be permitted to take place during normal operating hours Monday-Friday. Both parties shall aim to blast between 10:00pm and 4:00pm on blasting days. Blasting shall not take place outside of normal operating hours Monday-Friday. The environmental conditions on site as per the planning consent are such that ground vibration, measured as a maximum of three mutually perpendicular directions taken at the ground surface at or near the foundations of any vibration sensitive building or residential premises, does not exceed a peak particle velocity (PPV) of 6mm per second in 95% of all blasts.

The first stage of the blasting process is blast design, this is where key decisions are made to manage blast performance and environmental compliance.
The EPC-UK blasting engineer produces a blast design for each blast. The blast design specifies the pattern of blast holes (also known as the Drill Pattern and dictates spacing, burden, depth, inclination, and azimuth) and the way in which the holes are to be charged and sequenced for detonation.
The pattern is designed to comply with ground vibration limits placed on the quarry, and at this point, this is to be verified by predicting ground vibration levels and deciding on the Maximum Instantaneous Charge (MIC) available.
To further improve the accuracy and prediction of the ground vibration level and decision making process of the MIC a regression model shall be created. The benefit of this is detailed later in this document.

Control Measures on the Environmental Impact of blasting

Electronic Initiation:

EPC-UK design each blast individually based on previous environmental results and extensive site knowledge & experience. The preferred method of initiation at Denbigh is the use of the Hybrid system.
Hybrid Initiation comprises of a primary detonator and a secondary detonator.
The primary initiation system is the electronic detonator. These are widely accepted in the explosives industry to offer the greatest accuracy of detonation offering millisecond precision timing. The outcome of this is the blast is fired in accordance with it's designed timings. This ensures the quantity of explosives detonating at any one time (MIC) is controlled therefore managing vibration levels.

The secondary initiation system is the non-electric detonator. These offer a robust back up in the already unlikely event of a misfire on the primary initiation system.

Comprehensive Blasting Database and Experience:

A comprehensive blast database and history of blasting onsite is held by EPC-UK and Breedon Trading Limited after many years of a customer/supplier relationship. This experience and history enable accurate prediction and decision making when choosing the MIC and delay timings of the electronic detonators. This is continually updated, reviewed and used to further improve prediction, understand any non-conformances and manage/mitigate future blasting operation environmental impacts.

Planning to comply – Regression Model:

EPC-UK will with Breedon at Denbigh create a regression model for further improved compliance. The regression model will create as detailed below a line of best fit based on distances to monitoring locations specified. This will provide accurate pre-predictions on MIC to comply with the 95% confidence limit and guide blast design decision making, importantly this decision making is relevant to the Denbigh site and will apply a scientific method for environmental impact management and mitigation.

Vibration prediction – Further Information

Several factors influence the ground vibration levels from blasting. The most obvious factors are the distance from the blast to the location or locations of concern and the size of the explosive charge. Both factors are easily determined for a given blast.
The other key factors are the geometry of the blast and the nature of the ground through which the ground vibrations travel. These are far less easy to account for theoretically, and so an empirical approach must be taken to allow predictions to be made.

D.1 Scaled Distance Relationship

Over many years, the idea of a scaled relationship of distance and charge weight with vibration levels has been seen to be broadly accurate.

Scaled Distance (SD) = dist /√MIC (or dist/MIC^0.5)
dist = distance from blast to monitoring point
MIC = Maximum Instantaneous Charge (The maximum amount of explosive that is detonated at one particular moment).

The influence of blast design and geology (rock-type, structure and surface features) are accounted for using two site factors – a & b.
The relationship between ground vibration (measured as Peak Particle Velocity or PPV) and the factors listed previously is given as

PPV = a * (SD)^b

a & b are site factors and SD is Scaled Distance

This allows the PPV to be predicted, if the SD and the site factors are known. The SD can be determined from the blast design, but it is virtually impossible to calculate the site factors theoretically. However, they can be determined empirically by analysing historical or test blast data through the use of regression analysis. This is relatively simple because the above equation can be re-written as:

$$\log(PPV) = b * \log(SD) + \log(a)$$

This is helpful because it has the form of $y = m * x + c$ which is the equation of a straight line with gradient m and intercept (crossing the x-axis) c.
Plotting or "regressing" log(PPV) against log(Scaled distance) often reveals a linear relationship that can be defined by the gradient of the line (b) and the intercept (log(a)), which can both be determined by regression analysis.

D.2 Prediction of Vibration

Once the site factors (a & b) have been determined by monitoring and calculation, and the blast-receptor distance and charge weight (MIC) for a future blast have been measured and selected, the amplitude of vibration can be predicted from:

$$\log(PPV) = b * \log(dist / \sqrt{MIC}) + \log(a)$$

However, the accuracy of this prediction needs to be determined. In least-squares regression analysis the goodness of fit of the model is determined using the Correlation Coefficient (r^2) and the Standard Error (SE). The higher the correlation coefficient (on a range of 0 to 1), and the lower the standard error, the better the prediction will be.
The Correlation Coefficient can usually be improved by monitoring vibrations at a large range of distances from the blast, not simply at local properties when monitoring for compliance. This may require monitoring within the quarry as well as additional locations outside the quarry boundary.

A. Protocol for Planning (Designing) to Comply

For Denbigh a PPV limit has been set by the council for compliance as part of its planning consent. The blasting engineer of EPC-UK has to decide whether the charge of explosive they would like to use for the blast is predicted to result in PPV levels that exceed the consent level. If so, then the engineer will have to calculate the maximum amount of explosive they can use in order to stay within the vibration limit. This is known as planning, or designing, to comply.
The procedure here is to use the limiting PPV to produce a Scaled Distance for that site which can then be used to determine what charge weights are safe to use. The use of appropriate sub-sets of the database for the calculations for blasts of a particular type or in a particular location (as described in Appendix D.3) can increase the accuracy and so should be used where the data allows.

If:

$$\log(PPV) = b * \log(SD) + \log(a),$$

then re-arrange to make Scaled Distance the subject to give:

$$\log(SD) = (\log(PPV) - \log(a)) / b \quad \text{or} \quad SD = 10 \wedge ((\log(PPV) - \log(a)) / b)$$

As a and b are known and PPV is defined, then SD can be calculated.

Once the SD has been obtained then the Maximum Instantaneous Charge weight (MIC) can be calculated for a given distance using the equation:

$$SD = dist / \sqrt{MIC}, \text{ so } \quad MIC = (dist/SD)^2$$

However, this is based on the best fit line which will have 50% of the points above it and 50% of the points below. The predictions will therefore give an average PPV value that will have a 50% probability of being exceeded. Usually a 95% confidence limit is required, so rather than take the best fit (50%) line the equation of a line which has 95% of the points below (the 95% line) it is determined and used for the prediction.
The gradient of the 95% line will be the same as the best-fit line, so the site factor b remains the same. The intercept of the straight line (log(a)) however will be different as the 95% line is higher. Graphically it can be seen that 95% of points plot below it, rather than 50% with the best-fit line (see the example given in Figure 2). The difference in intercepts is a multiple of the Standard Error (SE), the multiple being a function of the normal distribution scatter about the best fit line. For 95%, the multiplier is 1.645.
Designing to comply with an absolute (100%) limit is impossible because of the scatter in the monitored data. Considerable experience has shown that if the limit of 95% at 6 mm/s is designed for and complied with, then it is extremely unlikely that any blast vibrations will exceed 10 mm/s.

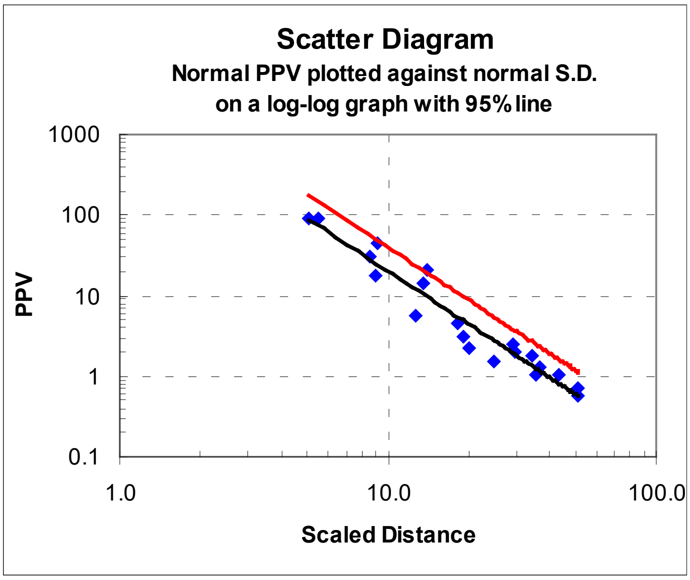

Figure 1: Example of PPV - Scaled Distance plot with 50% (blue) and 95% (red) confidence lines marked

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The intercept of the 95% line (a95%) is therefore

log(a95%) = log(a) + (1.645 * SE)

There is often some confusion about whether the 1.645 or 1.96 multiplier should be used for a 95% confidence limit. The 1.96 multiplier would be used for 95% of points between an upper and a lower limit (twin tail). However, in planning conditions the 95% is an upper limit only, so it doesn't matter how much below the predicted value a PPV result is. A single tail is therefore used and the multiplier for 95% is 1.645.

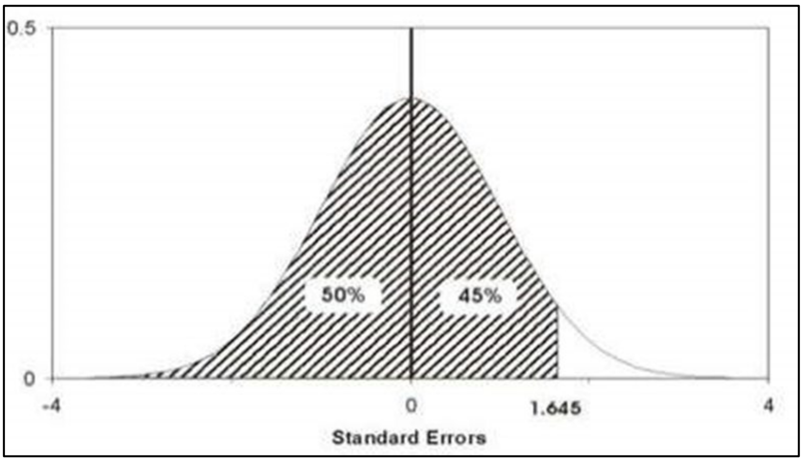

Figure 2: Single tail multiplier

The equation for the Scaled Distance at the 95% confidence line is therefore:

SD95% = 10 ^ ((log(PPV95%) – (log(a) + (1.645 x SE))) / b)

The Scaled Distance value for the 95% level can now be used in the equation below to determine the Maximum Instantaneous Charge weight (MIC) which should be used to be 95% certain of producing a vibration value less than the limit.

MIC = (dist/SD95%)^2

In most cases, the MIC of choice will be much lower than the maximum amount determined from the above equation. It is only when the normal blast design requires an MIC which exceeds the limit that action needs to be taken to reduce the MIC used in the blast without significantly altering the blast ratio (amount of explosive per tonne of rock). In some circumstance this can be achieved by:

- pulling in the centres (reducing burden & spacing) with less charge in each hole. This will maintain the blast ratio, but the drilling costs will go up and the charge may no longer be distributed through the shothole in a favourable manner. This could be remedied by using a narrower hole, but this has knock-on effects and there may not be a smaller drill bit available.
- splitting the charge in each hole into two (or more) decks on separate detonator delay times, this reducing the MIC. This is often the chosen method.

Both Breedon Trading Limited and EPC United Kingdom Limited are committed to ensuring environmental compliance to the planning consent, utilising the expertise of both parties, managing the environmental impact of blasting is achievable. Using electronic initiation systems and operating a 'planning to comply' approach for predicting vibration levels before blasting enables positive control and compliance to the planning consent limits.

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