C/S 411

Assessment of the Environmental Effects of Blasting at Craig Yr Hesg Quarry with respect to Proposals for future Working in accordance with Rhondda Cynon Taff Unitary Development Plan

undertaken on behalf of

HANSON AGGREGATES

No. R04.3450/1/TJW
30.04.04

VIBROCK

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VIBROCK

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1.0 INTRODUCTION

1.1 Rhondda Cynon Taff County Borough Council (RCT) are required to identify a Minerals Safeguarding Area for Craig yr Hesg Quarry in their emerging Unitary Development Plan (UDP) intended to be published in draft form by July 2004.

1.2 As part of their UDP, and in addition to determining a Mineral Safeguarding Zone, RCT have a duty to define a Buffer Zone around existing and allocated resources. Paragraph 71 in the MTAN (Wales) 1 refers to the adoption of a minimum distance of 200m around hard rock quarries unless there are "clear and justifiable reasons" for reducing the distance.

1.3 Paragraph 42 of MTAN (Wales) 1 recognises that the Pennant Sandstones of South Wales, as quarried at Craig Yr Hesg, are of UK importance and therefore considers this material as a '**special case**'.

1.4 This fact is referred to by RCT's minerals planning officer in correspondence with Hanson Aggregates where it is suggested that this could be construed as one of the "clear and justifiable reasons" for reducing the minimum separation distance from 200 metres.

1.5 MTAN (Wales) 1, however, gives no indication of the extent to which such a Buffer Zone may be reduced.

1.6 In order to be able to assess the significance of blasting operations at Craig Yr Hesg Quarry, specifically with respect to the 200 metres separation distance and to any reduction to this figure, Hanson Aggregates have commissioned a blast vibration assessment to be undertaken at the quarry.

1.7 Vibrock Limited, an independent environmental consultancy specialising in the field of blast induced vibration, were chosen to undertake this assessment which is described in detail within this report.

2.0 EFFECTS OF BLASTING

2.1 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.

2.2 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.

2.3 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.

2.4 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.

3.0 BLAST VIBRATION TERMINOLOGY

3.1 Ground Vibration

3.1.1 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.

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

3.1.3 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).

3.1.4 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 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.

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

3.1.6 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

3.1.7 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.

3.1.8 Such maximum of any one plane measurements is the accepted standard worldwide and as recommended by the British Standards Institution and the International Standards Institute 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.

3.1.9 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.

3.1.10 All research and previous work undertaken has indicated that any vibration induced damage will occur immediately if the damage threshold has been exceeded and that there is no evidence of long term effects.

3.2 Airborne Vibration

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

3.2.2 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.

3.2.3 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.

3.2.4 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.

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

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

3.2.6 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.

3.2.7 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.

3.2.8 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.

3.2.9 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.

3.2.10 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.

3.2.11 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.

4.0 VIBRATION CRITERIA

4.1 Damage Levels

Ground Vibration

4.1.1 Various authorities around the world have undertaken detailed research into determining the vibration levels necessary for the possible onset of damage to property. The United States Bureau of Mines (USBM) have reviewed all relevant published data, both theoretical and practical, to augment their own considerable research. They are, therefore, considered to be the foremost authority on this subject.

4.1.2 When defining damage to residential type structures the following classifications are used:-

Cosmetic or threshold	-	the formation of hairline cracks or the growth of existing cracks in plaster, drywall surfaces or mortar joints.
Minor	-	the formation of large cracks or loosening and falling of plaster on drywall surfaces, or cracks through bricks/concrete blocks.
Major or structural	-	damage to structural elements of a building.

4.1.3 Published damage criteria will not necessarily differentiate between these damage types but rather give levels to preclude cosmetic damage and therefore automatically prevent any more severe damage.

4.1.4 The comprehensive research programme undertaken by the USBM in the late 1970's (R.I. 8507, 1980) determined that vibration values well in excess of 50 mms^{-1} are necessary to produce structural damage to residential type structures. The onset of cosmetic damage can be associated with lower vibration levels, especially at very low vibration frequencies, and a limit of 12.7 mms^{-1} is therefore recommended for such relatively unusual vibration. For the type of vibration associated with open pit blasting in this country, the safe vibration levels are seen to be from 19 - 50 mms^{-1}.

4.1.5 A further USBM publication (Bureau of Mines Technology Transfer Seminar, 1987) states that these safe vibration levels are "....for the worst case of structure conditions....", and that they are "....independent of the number of blasting events and their durations", and that no damage has occurred in any of the published data at vibration levels less than 12.7 mms^{-1}.

4.1.6 Their latest publication on this subject (S.E.E. Conference, 1991) reconfirms these safe vibration criteria and states that "....these studies have since been widely adopted by the users and regulators of explosives to develop and demonstrate safe blasting practices." and that "In the ten years since their publication, nothing has appeared to replace them or even significantly add to the data base."

4.1.7 Indeed, within the UK, the Transport and Road Research Laboratory in their Report No. 53 of 1986 recommend the use of these USBM safe vibration criteria for blasting adjacent to residential type structures.

4.1.8 In addition, the British Standards Institution's structural damage committee have investigated blast induced vibration with respect to its damage potential. They contacted some 224 organisations, mainly British, and found no evidence of any blast induced damage at levels less than those recommended by the USBM.

4.1.9 This investigation has culminated in British Standard 7385: Part 2: 1993, Evaluation and Measurement for Vibration in Buildings, entitled Guide to Damage Levels from Groundborne Vibration.

4.1.10 British Standard 7385 gives guide values to prevent cosmetic damage to property. Between 4 Hz and 15 Hz, a guide value of 15 - 20 mms^{-1} is recommended, whist above 40 Hz the guide value is 50 mms^{-1}. These vibration criteria reconfirm those of the USBM.

4.1.11 Any doubt that such low levels of vibration are perfectly safe should be dispelled by considering the strain induced within a residential type property from daily environmental changes and domestic activities. This is confirmed within the 1987 USBM publication which quotes that daily changes in humidity and temperature can readily induce strain of the order that is equivalent to blast induced vibration of from 30 - 75 mms^{-1}. Typical domestic activities will produce strain levels corresponding to vibration of up to 20 mms^{-1} and greater.

4.1.12 It is for this reason that many domestic properties will exhibit cracks that may be wrongly attributed to blasting activities. There are many additional reasons why properties will develop cracks, for example:-

Fatigue and ageing of wall coverings.
Drying out of plaster finishes.
Shrinkage and swelling of wood.
Chemical changes in mortar, bricks, plaster and stucco.
Structural overloading.
Differential foundation settlement - particularly after times of prolonged dry spells.

Air Overpressure

4.1.13 Comprehensive investigations into the nature and effects of air overpressure with particular reference to its damage potential have been undertaken by the United States Bureau of Mines who have also reviewed all other published data on this subject (R.I. 8485, 1980).

4.1.14 The weakest parts of most structures that are exposed to air overpressure are windows. Poorly mounted, and hence prestressed windows might crack at around 150 dB (0.1 p.s.i.) with most cracking at 170 dB (1.0 p.s.i.). Structural damage can be expected at 180 dB (3.0 p.s.i.).

4.1.15 The latest recommendations by the United States Bureau of Mines are as follows:-

Instrument Response	***Maximum Recommended Level***
0.1 Hz high pass	134
2.0 Hz high pass	133
5.0 or 6.0 Hz high pass	129
C- Slow	105 dB (C)

4.1.16 This set of criteria is based on minimal probability of the most superficial type of damage in residential-type structures, the single best descriptor being recommended as the 2 Hz high pass system.

4.2 Perception Levels

4.2.1 The fact that the human body is very sensitive to vibration can result in subjective concern being expressed at energy levels well below the threshold of damage.

4.2.2 A person will generally become aware of blast induced vibration at levels of around 1.5 mms^{-1}, although under some circumstances this can be as low as 0.5 mms^{-1}. Even though such vibration is routinely generated within any property and is also entirely safe, when it is induced by blasting activities it is not unusual for such a level to give rise to subjective concern. Such concern is also frequently the result of the recent discovery of cracked plaster or brickwork that in fact has either been present for some time or has occurred due to natural processes.

4.2.3 It is our experience that virtually all complaints regarding blasting arise because of the concern over the possibility of damage to owner-occupied properties. Such complaints are largely independent of the vibration level. In fact, once an individual's perception threshold is attained, complaints can result from 3% to 4% of the total number of blasts, irrespective of their magnitude.

4.2.4 An explanation of the necessity to use explosives and the likely effects as perceived by a site's neighbours can allay the concern of a significant proportion of those inhabitants of neighbouring property. It is invariably the case that an operator will consider the perception threshold level prior to the design of each and every blast at a particular site.

4.2.5 The British Standards Institution have produced a document relevant to such a discussion entitled BS 6472: 1992, British Standard Guide to Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz). Blasting vibration is specifically mentioned within Appendix C of this document. The document also discusses how and where to measure vibration. This appendix recommends that a satisfactory magnitude of blasting vibration at residential type property is 8.5 mms^{-1} at a 90% confidence level, with an absolute limit of 12.7 mms^{-1}.

4.2.6 The latest Government guidance on this subject is given within MPG 9, 1992 and MPG 14, 1995 where a range of between 6 to 10 mms^{-1} at a 95% confidence level is suggested as measured over any period of 6 months at vibration sensitive buildings with no individual blast exceeding 12 mms^{-1}.

4.2.7 These same criteria are also recommended within the 1998 Department of the Environment Transport and The Regions research publication, The Environmental Effects of Production Blasting from Surface Mineral Workings.

4.2.8 This same DETR publication also notes that "It would appear that over the years conditions have become progressively more stringent. No doubt this is as a result of MPAs seeking to reduce the number of complaints and by operators seeking to resolve issues more quickly. However, a reduction in complaints will not necessarily follow".

4.2.9 Indeed, one of the principal findings of the study which lead to this publication is "Once the threshold of perception had been crossed the magnitude of vibration seemed to bear little relation to the level of resulting complaint".

4.2.10 Paragraph 83 in MTAN (Wales) 1 states that planning conditions should provide for a:-

- maximum level of ground vibration at vibration sensitive locations: ground vibration as a result of blasting operations should not exceed a peak particle velocity of 6 mms^{-1} ppv in 95% of all blasts measured over any 6 month period, and no individual blast should exceed a peak particle velocity of 10 mms^{-1} ppv.

5.0 PREDICTION AND CONTROL OF VIBRATION LEVELS

5.1 Ground Vibration

5.1.1 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.

5.1.2 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

5.1.3 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.

5.1.4 An empirical relationship derived by the 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

5.1.5 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

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

5.1.7 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.

5.1.8 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.

5.1.9 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 $mkg^{-1/2}$ corresponding to the vibration level required

5.1.10 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.

5.1.11 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.

5.1.12 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.

5.1.13 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.

5.1.14 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.

5.1.15 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.

5.2 Airborne Vibration

5.2.1 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.

5.2.2 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 6 dB. 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.

5.2.3 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.

5.2.4 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.

5.2.5 Such a procedure is recommended by the Government in their latest publications on this subject, MPG 9 of 1992 and MPG 14 of 1995, where it is suggested that no air overpressure limit be defined but rather that methods to be employed to minimise air overpressure are submitted for approval. This approach is also recommended within the previously mentioned 1998 DETR publication, and MTAN (Wales) 1: Aggregates.

5.2.6 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.

5.2.7 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.

5.2.8 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.

6.0 BLAST VIBRATION DATA

6.1 Levels of vibration from a typical production blast were measured on site from a blast initiated at 1300 hours on 22nd April 2004. Table 1 details the blast specification with Plan 1 illustrating the seismograph locations.

6.2 The resulting vibration data, given in Table 2, has been used together with the USBM formula to predict vibration levels. This calls for the maximum peak particle velocity (PPV) to be plotted against scaled distance (SD) in a logarithmic manner. The latter is defined as:-

$$\text{Scaled Distance (mkg}^{-1/2}\text{)} = \frac{\text{blast/receiver separation distance (m)}}{(\text{MIC})^{0.5}}$$

where MIC is the maximum instantaneous charge weight in kg.

6.3 In addition, for any given vibration criterion and distance the allowable maximum instantaneous charge weight can be determined.

6.4 This site regression line is given in Figure 1.

7.0 DISCUSSION

7.1 The least squares analysis of the site data obtained from the blast of 22nd April 2004 is given in Figure 1 with the corresponding 95% confidence level.

7.2 In this instance there is clearly some indication that vibration levels to the rear of the shot are slightly greater than those to the side or in front. Such variation is regularly noted from quarry blasting and is a result of blast geometry.

7.3 Although the scaled distance value for 6 mms^{-1} at 95% confidence, as recommended in MTAN (Wales) 1: Aggregates, for all data is very similar to that for rear data only (19.7 $mkg^{-1/2}$ for all data, 20.5 $mkg^{-1/2}$ for rear) in order to consider worst case conditions it is the latter value that is illustrated in Figure 1 and used for the interpretation in Table 3.

7.4 It should also be noted that this production shot involved a tight end, again a worst case condition for blast vibration.

7.5 Inspection of Table 3 shows that the allowable maximum instantaneous charge weight at 200 metres separation distance is some 94 kg., virtually identical to that employed in the monitored blast.

7.6 Such a charge could, whilst still maintaining the site criterion of 6 mms^{-1} at 95% confidence, be reduced in line with the figures of Table 3 as the 200 metres distance is reduced.

7.7 Hence, for example, at 180 metres a reduced charge of 76 kg. would apply with 60 kg. at 160 metres, 46 kg. A t 140 metres etc.

7.8 In practice, such a charge reduction is routinely occasioned by means of decking, a procedure whereby a length of inert material such as chippings is introduced into each borehole to divide the explosive charge into 2, or more, discrete amounts.

7.9 Hence, for example, one deck per hole would readily accommodate an instantaneous charge weight of 50 kg equivalent to a stand off distance of around 150 metres whilst still complying to the recommended vibration criterion.

7.10 Further charge weight reductions are possible by other means for example, by a reduction in the borehole diameter and/or the face height.

8.0 CONCLUSIONS

8.1 A typical blast, albeit worst case in terms of vibration, at Craig Yr Hesg Quarry has been measured in terms of the vibration generated.

8.2 This vibration has been analysed according to the least squares regression technique in order to be able to establish expected future worst case vibration levels at differing blast/receiver separation distances.

8.3 This analysis is expected to be useful in the determination of suitable future rock extraction areas at the quarry site.

9.0 REFERENCES

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

3. BS 6472: 1992 Evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz). British Standards Institution.

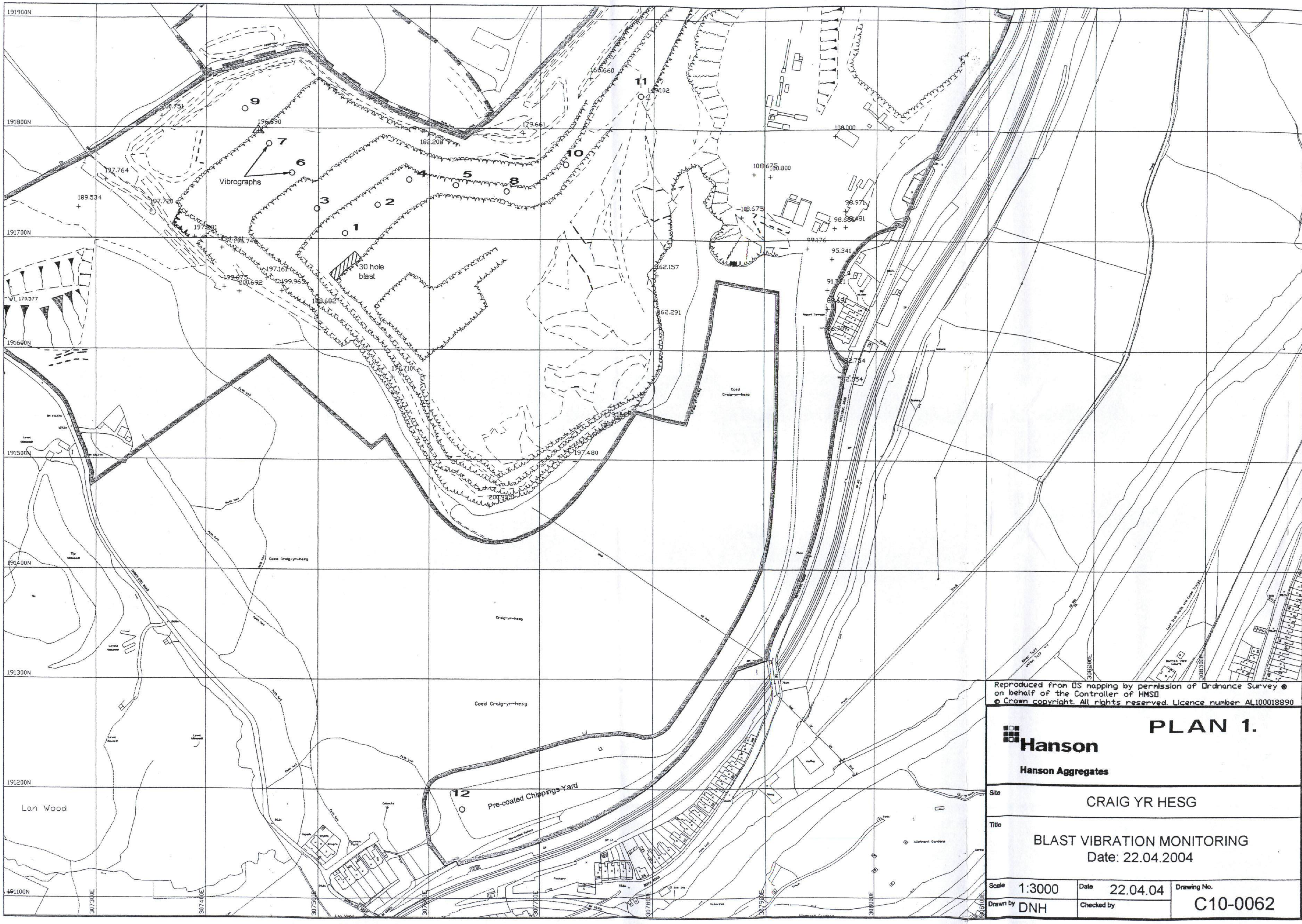
4. Minerals Planning Guidance Note No. 9, 1992 Planning and Compensation Act 1991: Interim Development Order Permissions (IDOS) - Conditions. Department of the Environment, Welsh Office.

5. Minerals Planning Guidance Note No. 14, 1995 Environment Act 1995: Review of Mineral Planning Permissions. Department of the Environment, Welsh Office.

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

7. Minerals Planning Policy (Wales) Minerals Technical Advice Note MTAN (Wales) 1: Aggregates, February 2004, Welsh Assembly Government.

PLAN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PLAN 1.
Hanson
Hanson Aggregates
Site
CRAIG YR HESG
Title
BLAST VIBRATION MONITORING
Date: 22.04.2004
Scale 1:3000
Date 22.04.04
Drawing No.
C10-0062
Drawn by DNH
Checked by
Vibrographs
30 hole blast
Pre-coated Chippings Yard
Lan Wood
191900N
191800N
191700N
191600N
191500N
191400N
191300N
191200N
191100N
307300E
307400E
307500E
307600E
307700E
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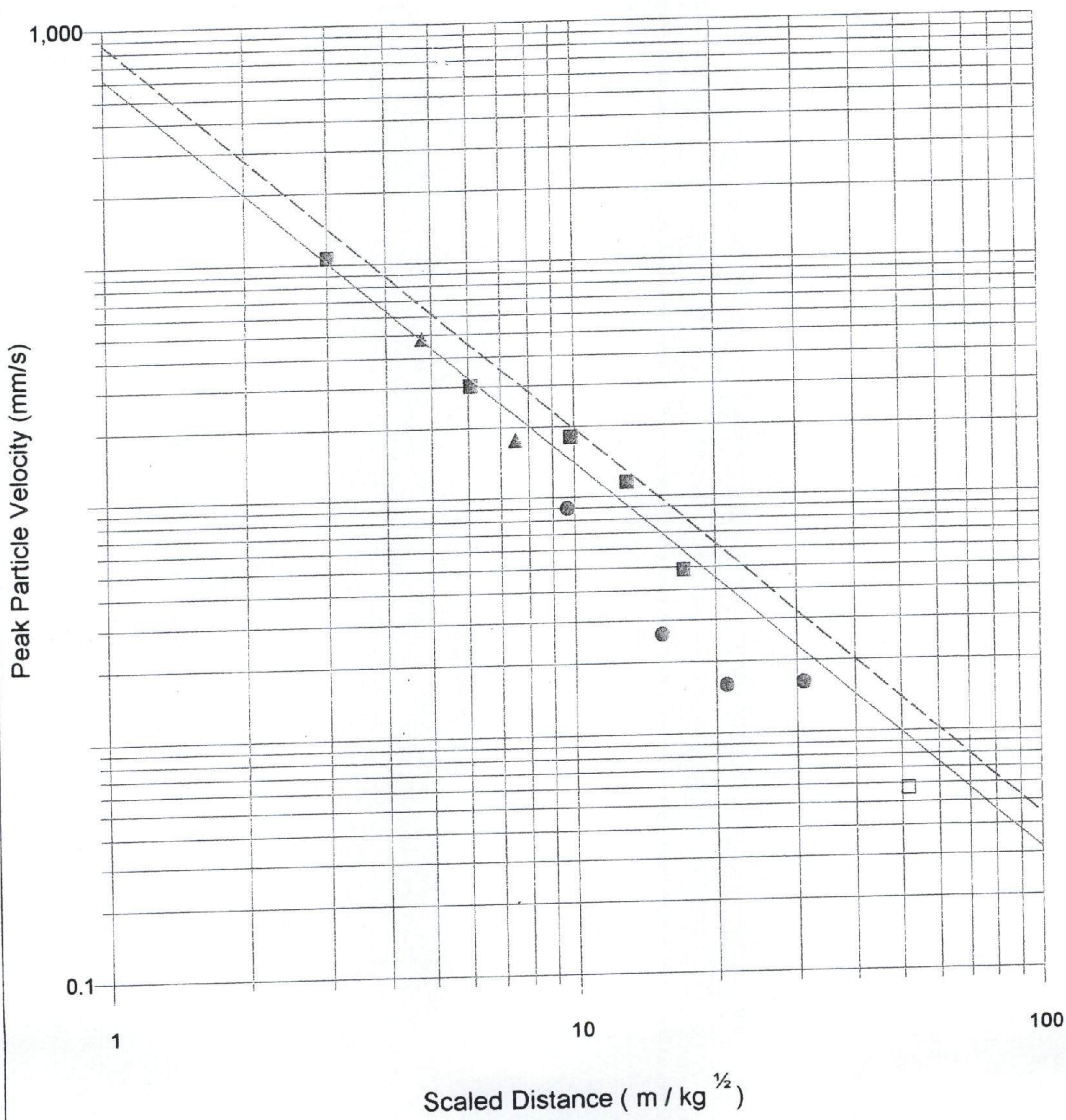
307900E
308000E
308100E
308200E
308300E

FIGURE

Figure 1. Craig Yr Hesg Quarry Regression Line.



50.00% Confidence
95.00% Confidence

■ Behind Shot
▲ Behind/Side of Shot
● Side of Shot
□ Front of Shot

Graph plotted for selected points only.
Points included : Behind Shot, Behind/Side of Shot
Points excluded : Side of Shot, Front of Shot

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TABLES

TABLE 1

BLAST DETAILS AT CRAIG YR HESG

Date:	22nd April 2004
Time:	1300 hours
No. of Holes:	30
Diameter:	110 mm
Depth:	16.0 metres
Burden:	3.5 metres
Spacing:	3.5 metres
Maximum Instantaneous Charge Weight:	95.0 kg
Total Explosive Charge Weight:	2725.0 kg
Blast Reference:	No E 42
Comments:	Tight end

TABLE 2

VIBRATION RESULTS

Distance to Seismograph metres	***Peak Particle Velocity mms^{-1}***			***Air Overpressure dB***
	Long	***Vert***	***Trans***	
1. 29.3 (R)	91.0	106.0	76.0	-
2. 46.5 (R/S)	43.0	48.0	27.0	-
3. 59.0 (R)	30.0	20.0	16.8	-
4. 73.0 (R/S)	17.6	11.5	12.7	
5. 94.0 (S)	7.27	3.82	9.02	-
6. 96.0 (R)	18.0	10.8	13.6	130
7. 126.0 (R)	11.5	5.1	10.4	-
8. 148.5 (S)	2.62	1.75	2.02	-
9. 166.0 (R)	4.85	2.72	4.37	-
10. 204.5 (S)	1.60	0.795	1.01	-
11. 302.0 (S)	1.62	0.825	1.07	109
12. 501.0 (F)	0.575	0.350	0.450	103

(R) = Rear of shot

(R/S) = Rear/To side of shot

(S) = To side of shot

(F) = In front of shot

TABLE 3

INTERPRETATION OF REGRESSION LINE

PPV Limit	6 mms^{-1}
Confidence Level	95%
Closest Distance	100 metres
Furthest Distance	300 metres
Step Interval	10 metres
Scales Distance	20.5 $mkg^{-½}$

Blast/Receiver Separation Distance (metres)	***Maximum Instantaneous Charge Weight, kg***
100	23
110	28
120	34
130	40
140	46
150	53
160	60
170	68
180	76
190	85
200	94
210	104
220	114
230	125
240	136
250	148
260	160
270	173
280	186
290	199
300	213

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