CONTENTS

INTRODUCTION

This chapter of the ES reports the findings of an assessment of the potential impact upon nearby receptors from vibration generated by blasting operations within the proposed extension. It is based on an assessment undertaken as part of a Periodic Review of Mineral Permissions (ROMP). This assessment identifies a range of measures which may be used to enable any identified impacts to be minimised and mitigated.

12.1 The proposed extension is located at some distance from the nearest receptors, with workings in the consented quarry being undertaken at closer distances to the receptors. Allied to this, unlike conventional aggregate quarries, blasting is not undertaken on the same scale. In view of this, it is considered appropriate and proportionate to review the previous assessment undertaken in 2016 to understand the likely significance of any effects and draw out any areas where there may be a difference as a result of developing the proposed extension.

12.2 The effects of blasting upon local communities, in terms of wellbeing, is also addressed in Chapter 13 of this ES.

METHODOLOGY

Scoping

12.3 As noted in Chapter 4 above, a formal scoping request was submitted in November 2018, with the MPA issuing their Scoping Opinion in January 2019. The scoping request considered that the effects of blast induced vibration could be scoped out of the EIA given the separation distance between the extension and the nearest receptors. However, the scoping opinion stated:

"The assessment must show that the levels of noise, blasting and air overpressure are within acceptable limits."

Government Advice, Standards and Good Practice

British Standard 6472-2:2008

12.4 British Standard 6472:2008 *Guide to evaluation of human exposure to vibration in buildings* Part 2: *Blast-induced vibration* gives guidance on human exposure to blast-induced vibration in buildings and is primarily applicable to blasting operations associated with mineral extraction.

12.5 BS6472-2:2008 advises on the maximum satisfactory magnitudes of vibration for residential properties. As blasting within the application site (in common with the established operations in the extant quarry) would only be undertaken during the daytime period, Table 12-1 details those maximum satisfactory magnitudes for the daytime period.

Table 12-1
Maximum satisfactory magnitudes of vibration with respect to human response for up to three blast vibration events per day

Place	Time		Satisfactory magnitude ppv mm/s
Residential	Daytime	08:00 to 18:00 hrs Monday to Friday 08:00 to 13:00 hrs Saturday	6.0 to 10.0

12.6 As the British Standard is concerned with human response within the buildings, the external levels are set so as to achieve satisfactory internal levels.

12.7 The British Standard also sets out how such limits should be reduced if blasting occurs on more than three occasions per day by detailing a formula based on the number of blasts, the duration of the vibration and a constant which is governed by the type of floor and duration.

12.8 Finally, the standard details a method of predicting vibration at nearby vibration-sensitive receptors from previously measured blasting events such as test blasts or historical blasting data gathered as part of a blast vibration monitoring scheme.

British Standard 7385-2: 1993

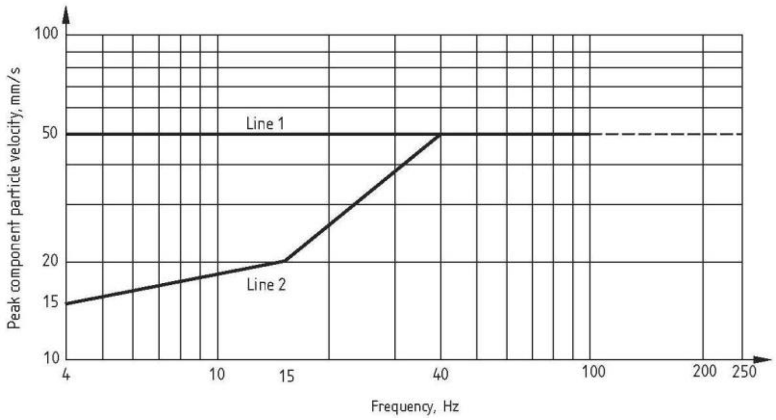
12.9 BS 7385-2: 1993 *Evaluation and Measurement for Vibration in Buildings: Guide to Damage Levels from Groundborne Vibration* gives guidance on the levels of vibration above which building structures could be damaged. It identifies the factors which influence the vibration response of buildings, and describes the basic procedure for carrying out measurements. Vibrations of both transient and continuous character are also considered.

12.10 The standard comments on page 1 that there is a lack of reliable data on the threshold of vibration-induced damage in buildings both in countries where national standards already exist and in the UK. The standard has been developed from an extensive review of UK data, relevant national and international documents and other published data. Although a large number of case histories were assembled in the UK database, very few cases of vibration-induced damage were found. It was therefore necessary to refer to the results of experimental investigations carried out in other countries into vibration-induced damage thresholds.

12.11 British Standard 7385 gives guide values to prevent cosmetic damage to property. Between 4 Hz and 15 Hz, a guide value of 15 - 20 mm/s is recommended, whist above 40 Hz the guide value is 50 mm/s. Notwithstanding this, the standard also comments "*Minor damage is possible at vibration magnitudes which are greater than twice those given in Table [12-2], and major damage to a building structure may occur at values greater than four times the tabulated values*."

Table 12-2
BS7385 Cosmetic Damage to property

Line	Type of Building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	50 mm/s at 4 Hz and above
2	Unreinforced or light framed structures Residential or light commercial buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above
Note 1 – values referred to are at the base of the building Note 2 – for line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) is not to be exceeded			



Transient vibration guide values for cosmetic damage (BS 7385-2: 1993, pg 6)

12.12 At section 7.5.1 of the standard it addresses "*Fatigue considerations*". It states that:

"There is little probability of fatigue damage occurring in residential building structures due to either 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. … " It goes on to add that the guide values set out in Table 11-2 above should not be reduced from fatigue considerations.

Existing Planning Conditions Relating to Blast-induced Vibration

12.13 The planning history for the quarry has been set out in Chapter 2 above. Condition 26 of the current planning permission (ref. C16/1164/16/MW) states:

"Except as specified in condition 27 below, ground vibration as a result of any blasting operations shall not exceed a peak particle velocity of 6mm/sec. in 95% of all blasts measured over any 6 months period and no individual blast shall exceed a ppv of 10mm/sec. as measured at vibration sensitive property. PPV measurement shall be taken to be the maximum of three mutually perpendicular directions taken at the ground surface."

12.14 Condition 27 states:

"The maximum ground vibration created by any blasting operation as measured on the concrete wall of the crump weir at the Marchlyn dam spillway outfall shall not exceed 1mm/sec. ppv at any time."

12.15 Allied to this, Condition 24 controls the time of day when blasting can take place, condition 28 requires the monitoring of every blast and Condition 30 requires the blast designs to be calculated with the aid of the regression analysis.

ASSESSMENT

Ground Vibration Methodology

Operational Impact

12.16 The impact of blasting upon residential receptors will be determined with reference to BS 6472-2:2008. BS 6472-2:2008. This standard states that a satisfactory peak particle velocity (PPV) magnitude is between 6.0 to 10.0 mm/s.

Table 12-3
Operational Vibration Residential Receptors – Impact Magnitude

Magnitude	Description
Major	Limit value of 6 PPV mm/s exceeded by 4 PPV mm/s
Moderate	Limit value of 6 PPV mm/s exceeded by 3 PPV mm/s
Minor	Limit value of 6 PPV mm/s exceeded by 2 PPV mm/s
Negligible	Limit value of 6 PPV mm/s exceeded by 1 PPV mm/s
None	Limit value of 6 PPV mm/s not exceeded

The Significance of the Effect

12.17 The significance of the blasting effect will depend on the receptor type and its sensitivity to the blasting impact. The sensitivity of the receiving environment is shown in Table 12-4.

Table 12-4
Sensitivity Criteria for Blasting Receptors

Sensitivity	Definition
Very High	Residential properties (night-time), Schools and healthcare building (daytime)
High	Residential properties (daytime), Special Areas of Conservation, Special Protection Areas, Sites of Special Scientific Interest (or similar areas of special interest)
Medium	Offices and other non-noise producing employment areas
Low	Industrial areas

12.18 The sensitivity of the receiving environment together with the magnitude of impact defines the level of effect as shown in Table 12-5.

Table 12-5
Level of Effect Matrix

Magnitude	Sensitivity			
	Very High	High	Medium	Low
Major	Major	Major	Major	Moderate
Moderate	Major	Moderate	Moderate	Minor
Minor	Moderate	Minor	Minor	Negligible
Negligible	Negligible	Negligible	Negligible	Negligible
None	None	None	None	None

Operational Phase Blasting Effects

12.19 Blast-induced ground vibration is impulsive in nature and a typical time history would show a rapid build-up to a peak followed by a decay which might or might not involve several cycles of vibration. A typical blast consists of several boreholes into which are placed explosive charges. Each borehole is detonated individually using a series of detonators each with differing millisecond delays. Blast-induced vibration is measured in terms of unfiltered time histories if three component particle velocities from which the peak values can be identified.

12.20 The detonation of explosives within a confined borehole generates stress (seismic) waves causing localised vibration, distortion or cracking. This type of ground vibration is always generated, even by the most well-designed blasts, and will radiate away from the blast source, attenuating as distance increases. Research has concluded that the maximum value of particle velocity in any stress wave is the parameter of significance and is generally termed Peak Particle Velocity (PPV).

12.21 Research has concluded that the maximum value of particle velocity in any stress wave is the parameter of significance, and is generally termed peak particle velocity (ppv). Recognised best practice is to measure blast-induced vibration using a seismograph in terms of unfiltered time histories of three component particle velocities from which the peak values can be identified. As set out in BS 7385-2: 1993 measurements are taken on a well-founded hard surface at the base of the building on the side of the building facing the source of vibration; this is because in most instances, consideration is being given to compliance with prescribed limits. The vibration monitor is covered with a sandbag to ensure good contact with the ground and that the monitor does not bounce in response to a blast.

12.22 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 the blast induced waves can be accurately predicted at any location.

12.23 The accepted method of predicted peak particle velocity for any given situation is that of 'scaled distance'. BS6472-2:2008 states that in order to predict the likely vibration magnitude, a series of measurements at several locations should be taken from one or more trial blasts, in this case the data gathered from monitoring production blasts at the existing quarry has been used and total of 471 blasting events were measured and used in the assessment. The scaled distance value (s) for any location may be calculated as follows:

$$s = d/\sqrt{C}$$

where:

d is the separation distance (blast to receiver) in metres

C is the Maximum Instantaneous Charge (MIC) weight in kilograms (kg) i.e. maximum weight of explosive per delay interval in kg.

12.24 Vibration from blasting operations is routinely monitored and recorded by the applicant at locations around the quarry using up to three seismographs. Periodically, officers from the MPA attend the monitoring to check it is being carried out correctly and to check compliance with conditions. This data is used to inform the regression analysis which in turn is used to inform blast design.

12.25 The values have then been plotted against scaled distance on logarithmic scales, where scaled distance is the sum of the distance from the blast location to the receptor divided by the root of the maximum instantaneous charge weight, to give a blast regression line. Differing geology and blast design result in a degree of dater scatter. As noted in the Institute of Quarrying publication[1] (page 146) 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 plotted data are generally presented with the mathematical best fit or mean (50%) line through the data, calculated by least squares regression, together with an upper confidence level, which is generally taken as 95%.

12.26 The DETR Report notes that in theoretical terms the scaled distance approach based on a limit value of 12 mm/s ppv results in a 95% confidence levels of around 6 to 10mm/s with a mean or average value of around 3 to 5mm/s.

[1] The Use of Explosives in Quarrying. T E White and P Robinson. The Institute of Quarrying

Blast-induced Vibration-sensitive Receptors

12.27 Vibration predictions were made to the nearest residential properties to the approved extraction area and reported in Chapter 10 of the 2016 ES. The receptors selected were located in all directions around the quarry and were the same as specified for the assessment of noise (and requirement for noise monitoring). Of the receptors previously assessed 14 Gefnan and the Marchlyn Bach Reservoir are closest to the proposed extension; all other receptors are further from the extension than other parts of the approved quarry working. For completeness, details of the receptors previously assessed, and the results of the vibration assessment, are contained in **Appendix 12/1**.

Table 12-6
Sensitive Receptors

Property	Approx Distance used in previous assessment (m)	Closest distance from workings (m)	Approx Distance from Proposed Extension (m)
No.14 Gefnan	1,150	900	1,180
Marchlyn Bach Reservoir	930	930	1,130

Prediction and Control of Vibration Levels

Ground Vibration

12.28 BS6472-2:2008 states that in order to predict the likely vibration magnitude, a series of measurements at several locations should be taken from one or more trial blasts, in this case the data gathered from monitoring production blasts at a nearby quarry with similar geological characteristics has been used.

12.29 The applicant proposes to continue blasting in the same manner used for the existing quarry workings employing explosive maximum instantaneous charge weights of 120kg.

12.30 Blast vibration studies, undertaken by Vibrock Limited in August 1995 and March 2010, have been used for the basis of this assessment. Measurements were made of three blasting events at varying distances from the blast using MICs of 17.5kg, 25kg and 210kg. From the data recorded a scaled distance graph, or regression line, has been prepared. Table 12-7 shows the results of the measurements made by Vibrock Limited.

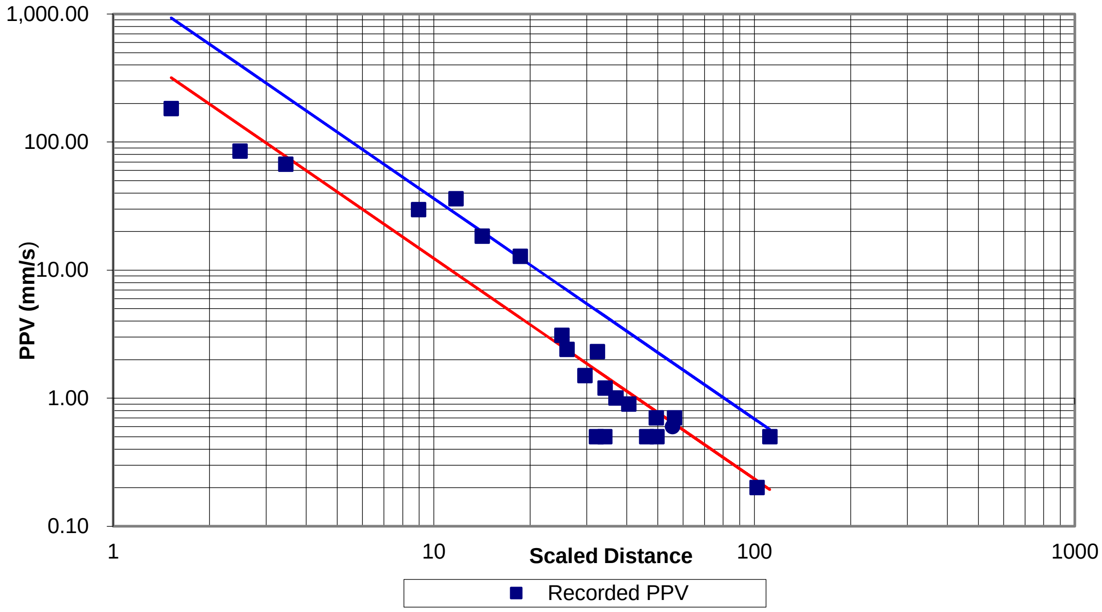
Table 12-7
Measured Vibration Levels

Distance from Blasting Event, m	MIC, kg	Measured Vibration level, mm/s ppv		
		Longitudinal	Vertical	Transitional
105	17.5	3.1	3.1	3.1
109		2.4	2.7	1.3
124		1.4	1.5	0.9
143		<0.5	<0.5	<0.5
193		<0.5	<0.5	<0.5
208		<0.5	<0.5	<0.5
233		0.6	0.4	0.4
488		<0.5	<0.5	<0.5
161	25.0	<0.5	<0.5	<0.5
162		1.9	2.3	1.9
171		1.2	0.5	0.5
185		1.0	0.4	0.5
203		0.9	0.4	0.5
247		0.7	0.4	0.3
282		0.5	0.7	0.5
510		0.2	0.2	0.1
22	210.0	182	132	124
36		67.6	84.8	71.2
50		51.6	67.2	63.6
130		29.6	26.8	25.6
170		32.4	36.0	12.4
205		18.4	16.4	17.2
270		12.8	4.0	6.8

12.31 The values have been plotted against scaled distance on logarithmic scales, where scaled distance is the sum of the distance from the blast location to the receptor divided by the root of the maximum instantaneous charge weight, to give a blast regression line. The plot includes the 95% confidence limit and is shown in Figure 12-1.

12.32 Recent monitoring data captured by the applicant has shown that blasts fail to trigger the monitoring equipment.

Figure 12-1
Blast Regression Line Model



12.33 Extrapolation of the regression line plot shown in Figure 12-1 shows that the corresponding scaled distance value for a vibration criterion of 6.0mm/s ppv at 95% confidence level is 28.5mkg$^{-1/2}$. The lower limit of satisfactory magnitude of 6.0mm/s ppv specified in BS6472 has been used for this assessment to ensure that the conditioned limit is achieved.

12.34 Table 12-8 shows the allowable maximum instantaneous charge weight to comply with this criterion at given separation distances.

Table 12-8
Allowable maximum instantaneous charge weights

Blast/receiver separation distance (m)	Allowable maximum instantaneous explosive charge weight to comply with criterion (kg)
100	12
125	18
150	28
175	38
200	49
250	77
300	110
350	151

Blast/receiver separation distance (m)	Allowable maximum instantaneous explosive charge weight to comply with criterion (kg)
400	197
500	308
600	443
700	604
800	788
900	998
1,000	1,232
1,100	1,491
1,200	1,774
1,300	2,082
1,400	2,415
1,500	2,773

12.35 The upper 95% confidence level has been taken as the basis for the interpretation of the maximum vibration levels likely. This shows that a stand-off of around 300m from the blast site to the receptor is required for a MIC of 110kg; this does not mean that blasting cannot approach closer than 300m, but alternative techniques/design (such as decking the charges) would be required. However, all receptors are located at much greater distances than 300m.

12.36 Table 12-9 shows the predicted maximum peak particle velocity for the vibration-sensitive receptors around the site using a MIC of 120kg.

Table 12-9
Predicted PPVs

Property	Approx Distance from Nearest Blast Location (m)	Predicted PPV using 120kg MIC	
		50% Confidence	95% Confidence
No.14 Gefnan	1,150	0.2	0.6
Marchlyn Bach Reservoir	930	0.3	0.9

12.37 Table 12-6 shows that the predicted vibration levels at the nearest vibration-sensitive receptors would be well below the criterion of 6mm/s at 95% confidence level when using an MIC of 120kg. Higher charge weights may be used at greater distances in accordance with the information shown in Table 12-5. In both cases, the actual distance between the receptor and the extension is slightly greater than that previously assessed; as such the predicted PPV would be lower.

12.38 Referring to Table 12-3 above as the limit of 6mm/s would not be exceeded, then the magnitude of impact is classed as ‘none’. With the nearby residential receptors being of ‘high’ sensitivity, then the resultant significance of the effect of blasting is ‘none’.

MITIGATION MEASURES

Good Practice – General

12.39 The means of controlling ground vibration, air overpressure and fly-rock have many features in common. Many of these measures are required for safety reasons by the Quarries Regulations 1999 and the approved Code of Practice.

- correct blast design is essential and should include a survey of the face profile prior to design, ensuring appropriate burden to avoid over-confinement of charge which may increase vibration by a factor of two;
- the setting out and drilling of shot holes should be as accurate as possible and the drilled holes should be surveyed for deviation along their lengths and, if necessary, the blast design adjusted;
- correct charging is obviously vital, and if free poured bulk explosive is used, its rise during loading should be checked. This is especially important in fragmented ground to avoid accidental over charging;
- correct stemming will help control air overpressure and fly-rock and will also aid the control of ground vibration. Controlling the length of the stemming column is also important; too short and premature ejection occurs, too long and there can be excessive confinement and poor fragmentation. The length of the stemming column will depend on the diameter of the hole and the type of material being used;
- monitoring of blasting and re-optimising the blast design in light of the results, changing conditions and experience should be carried out as standard; and
- avoid blasting in adverse/unsuitable weather conditions.

RESIDUAL EFFECTS

12.40 Blast-induced vibration is a short-term phenomenon lasting only for very short periods during the blasting event with no residual effects.

CUMULATIVE EFFECTS

12.41 The absence of any other quarries and the large separation distance between the quarry workings (as extended) and vibration sensitive receptors means that the likelihood of any significant cumulative effects is near zero. In this respect, vibration levels have been predicted at less than 1mm/s at the nearest receptor, which is well below the limits imposed in the current planning permission or indeed Welsh Government guidance.

CONCLUSION

12.42 An assessment of predicted blast-induced vibration levels has been made to the nearest vibration-sensitive residential receptors to the extraction area. The predictions are based on vibration levels measured by Vibrock Limited in August 1995 and March 2010.

12.43 The assessment has shown that the lower satisfactory magnitude level of 6.0mm/s ppv at 95% confidence can be achieved by suitable blast design using a maximum instantaneous charge weight of 120kg. the assessment has also shown that vibration levels would be below 1mm/s at the Marchlyn Bach Reservoir.

12.44 Therefore, vibration generated by blasting events is not considered to be a significant environmental factor in connection with the development of the proposed extension at Penrhyn Quarry.