

PAN 50 Annex D: Controlling the Environmental Effects of Surface Mineral Workings

Annex D: The Control of Blasting at Surface Mineral Workings

February 2000

Introduction

Background

1. This Annex to PAN 50 Controlling the Environmental Effects of Surface Mineral Workings provides advice to planning authorities and the minerals industry on how to keep the effects of blasting from surface mineral workings within environmentally acceptable limits. This Annex is based on the DETR commissioned research by Vibrock Limited The Environmental Effects of Production Blasting from Surface Mineral Workings, published by The Stationery Office 1998 [ISBN 0-11-753412-9] This Annex supersedes the advice in pages 13 to 15 of PAN 50 Controlling the Environmental Effects of Surface Mineral Workings.

2. Blasting at quarries and opencast coal sites can have adverse impacts that extend beyond the site boundary. Potential environmental impacts of blasting at surface mineral workings include ground vibration, air overpressure, noise, dust and flyrock. Where these effects are perceived at adjacent premises, particularly residential properties, there can be problems of reconciling the needs of efficient and economic mineral extraction with the comfort and well being of the site's neighbours.

3. Planning authorities should give full weight to the environmental effects of blasting at surface mineral workings and the potential disturbance to local communities. Where a proposal would cause demonstrable and material harm, permission should not be granted except where the benefits of the development proposal to the community would outweigh the potential harm. However, the planning system can control blasting times, set allowable levels of ground vibration, control overpressure, ensure monitoring of vibration levels and control dust and noise. The Scottish Executive seeks co-operation between operators and planning authorities so that sensible blasting regimes can be agreed for individual sites. The reasonable use of planning controls by planning authorities, in particular the use of conditions attached to planning permission, is an important means of ensuring that the effects of blasting at mineral sites do not pose a threat to the amenity of communities. Controls should be fair and reasonable, and should avoid measures that impose costs or constraints on the operator where there is no real benefit to local communities.

see NPPG16 Opencast Coal and Related Minerals, paragraph

4. The advice within this Annex should be used when considering new applications as well as reviewing and updating Interim Development Order (IDO) permissions and other old mineral permissions.

5. The advice within this Annex will also be relevant when reviewing and updating conditions attached to old mineral permissions.

Existing Controls

6. Planning authorities have an important role in controlling the environmental effects of blasting operations at surface mineral workings, but care should always be taken to ensure that planning controls do not conflict or replicate other existing statutory controls. It is vital that planning authorities are aware of other existing controls over blasting, so that they can properly assess proposals and respond to complaints.

7. Blasting operations at surface mineral workings were controlled by the Quarries (Explosives) Regulations 1988. These regulations detailed the duties of the site owner, manager and shotfirer in

the conduct of blasting operations. The health and safety implications of general quarry operations were controlled by The Quarries Miscellaneous Health and Safety Provision Regulations 1995. These regulations provided control over the possibility of flyrock. Both Regulations have been revoked by The Quarries Regulations 1999, which came into force on 1 January 2000.

8. Part 3 of the Environmental Protection Act 1990 places a mandatory duty on local authorities to investigate any complaints of nuisance and then take action where a nuisance is found, this includes nuisance from noise emissions and vibration. The relevant British Standard are: BS 5228 Noise and Vibration Control on Construction and Open Sites; BS 6472 Guide to Evaluation of Human Exposure to Vibration in Buildings; BS 7385 Evaluation and Measurement for Vibration in Buildings.

the need to blast

9. Blasting is not always an essential part of mineral operations, it is generally only required at rock quarries and opencast coal workings. However, at these sites the operators invariably consider blasting as an essential element of economic mineral extraction. There is usually no need for blasting at sand and gravel or peat mineral workings. Blasting may be required as part of the restoration scheme to create visually acceptable land forms or provide long term stability of a rock face.

10. Blasting in hard rock quarries is needed to break up in-situ material which cannot feasibly be removed by mechanical equipment. The most important factors that determine whether blasting is necessary are the hardness of the rock and the type of machinery available for extraction. In the case of opencast coal sites it is not the coal itself which may require blasting, but rather the rock strata or overburden above and in between the coal seams. The strata often needs to be loosened by the use of explosives in order that mechanical excavators can remove the material and thereby gain access to the coal. The need to blast overburden at opencast coal sites commonly increases with the depth of the mineral working, since the deeper layers of overburden contain fewer weaknesses in the form of joints, particularly in the case of sandstone layers. If there is uncertainty over whether blasting is required at an opencast coal site then a precautionary approach should be taken. It is better for mineral operators to plan for blasting than not to and find out that blasting is required once extraction starts.

11. Blasting as a means of rock removal is relatively expensive. A balance is required between the financial and environmental costs associated with blasting and the degree of fragmentation needed for mechanical extraction and/or crushing operations to be viable. Blasting can also be disruptive to the continuous operation of a site since personnel are required to be removed from the immediate blasting area in order for safe detonation to proceed. Hence, it is only when the immediate geological conditions render alternative extraction techniques either impossible or uneconomical that blasting is considered.

ground vibration

12. When an explosive detonates within a borehole it causes the rock in the immediate vicinity to crack or distort. Outside this immediate vicinity of the blast site permanent deformation does not occur, instead the rapidly decaying stress waves from the explosion cause the ground to exhibit elastic properties whereby the rock particles are returned to their original position as the stress waves pass. This causes ground vibration to radiate away from the blast site, the effect reducing as distance increases.

13. It is always in the operator's interest to reduce both ground and airborne vibration from blast events to the minimum possible for any specific blast design because it is this that substantially increases the efficiency, and therefore, economy of blasting operations. Despite this, even the best designed and executed blasts will generate a certain amount of unwanted energy in the form of ground vibration waves which will radiate away from the blast location.

Measurement

14. British Standard 7385: Part 1, 1990 discusses the measurement of vibration in buildings in general terms with more specific advice for damage investigation given in BS 7385: Part 2, 1993 and for human perception in BS 6472, 1992.

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

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

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

Particle 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).

16. In all standards the preferred parameter of measurement is peak particle velocity (ppv). The measurement of particles by vibration waves is usually measured in 3 mutually perpendicular directions, as particles will be oscillating in 3 dimensions, these are:

Longitudinal (sometimes termed radial) - back and forth particle movement in the same direction that the vibration wave is travelling.

Vertical - up and down movement perpendicular to the direction the vibration wave is travelling.

Transverse - left and right particle movement perpendicular to the direction the vibration wave is travelling.

Magnification Levels

17. The great majority of vibration recordings from surface mineral workings are undertaken either in order to demonstrate compliance with the sites planning conditions or in response to complaints. When recording vibration following receipt of complaints most commonly the complainant is concerned over the likelihood of damage to their property and therefore, in line with good practice and the guidance given in the relevant British Standard BS 7385, recordings are undertaken outside of property at ground surface immediately adjacent to the closest facade to the blast location.

18. It is vibration within a property which people experience most often and therefore in order to assess complaints regarding nuisance it may be necessary to monitor vibration within a property and at a location where the complainant considers the effects most noticeable in line with the BS 6472, 1992. These measurements should be taken in conjunction with those taken outside in order to be able to quantify any magnification effects. Magnification levels from 0.5 to 2.0 are most likely within low rise residential type structures. The actual magnification will depend upon many factors, but primarily the frequency content and to a lesser extent the duration of the incoming vibration and the natural frequencies of the building or parts of the building concerned.

19. In terms of damage, potential magnification effects are well known and are allowed for in the relevant standards. Guide values are invariably related to recordings to be undertaken at the base of the buildings or on the ground immediately outside of the building. This is the case with BS 7385 which also notes that maximum vibration will be found at mid-span locations on walls or floors but that such vibration is usually unrelated to structural integrity.

Effects of Frequency

20. The frequency content of blast vibration is a significant factor in determining magnification levels and both human and structural response to vibration. It is very largely determined by the geological conditions between the source and receptor, the distance from the source, and to a lesser extent, blast design and borehole geometry.

21. The more competent or solid the transmission medium, then the more the high frequency motions tend to be reduced or filtered out over shorter distances. Thus, ground motion frequencies will be relatively high when monitored close to a blast and/or when solid rock is present. Ground motion frequencies will be relatively low when monitored at a greater distance from a blast and/or when the transmission medium is relatively weak, such as clay or soil.

22. The typical range of ground vibration frequency for surface mineral workings is from 5 to 40 Hz, with levels predominantly from 20 to 30Hz in the case of hard rock quarries and 5 to 15Hz in the case of opencast sites with less competent transmission media. Hence, magnification of vibration within a structure is, perhaps, more likely with opencast blasting.

Human Response

23. Human response to blast induced ground vibration is a relatively complex phenomenon and is dependent upon a range of factors of which the actual vibration magnitude is only one and not necessarily the most important. It is well recognised that the human body is very sensitive to the onset of vibration albeit very poor at distinguishing relative magnitudes. Although sensitivity to vibration varies significantly between individuals, a person will generally become aware of blast induced vibration at levels of around 1.5mms⁻¹ peak particle velocity, and under some circumstances at levels as low as 0.5mms⁻¹.

24. Once a received vibration is greater than an individual's perception threshold then it is possible for concern to be expressed about the blasting. Such concern normally relates to the vibration's potential for causing damage to the complainant's property. Concern may be expressed that damage has already occurred due to the recent discovery of cracking that may have been present for some time or have been caused by natural processes. More often, however, concerns are based on the fear that damage will be caused at some time in the future as a result of repeated vibration.

25. The degree of concern and whether or not it leads to complaints is governed by many factors. Perhaps the most obvious is the vibration itself in terms of its magnitude, duration and frequency. However, the vibration magnitude at which complaints arise varies greatly from site to site such that no common complaint threshold exists. This is considered to be in part a reflection of the fact that individuals are very poor at distinguishing between vibrations of differing magnitudes.

26. The susceptibility of individuals to vibration will vary from person to person depending on factors such as age, health and, to a large extent, previous exposure. It is usually the case that adverse comments are less likely once a neighbour has become accustomed to the perceived effects of blasting. An explanation of the need to blast and the significance of the vibration levels being received by a site's neighbours are paramount as is an understanding and sympathetic attitude from the operator.

Effect on Structures

27. When defining damage to residential type structures the following classifications are used:

Cosmetic or threshold damage - the formation of hairline cracks or the growth of existing cracks in plaster, drywall surfaces or mortar joints.

Minor damage - the formation of large cracks or loosening and falling of plaster on drywall surfaces, or cracks through bricks/concrete blocks.

Major or structural damage - damage to structural elements of a building.

28. BS 7385 1993 gives guide values with respect to all 3 of these damage classifications for residential structures in terms of peak particle velocity and frequency. These values are based on the lowest vibration levels above which damage has been credibly demonstrated.

29. In terms of cosmetic damage, at a frequency of 4 Hz the guide value is 15mms⁻¹ peak particle velocity, increasing to 20mms⁻¹ at 15 Hz and 50mms⁻¹ at 40 Hz and above. Minor damage is possible at vibration magnitudes that are greater than twice those given for the possible onset of cosmetic damage with major damage to a building structure possible at values greater than four times the cosmetic damage values. These values apply even when a structure experiences repeated vibration events.

30. Although damage or the fear of damage is the major concern for neighbours of surface mineral workings the reality is that vibration levels at adjacent residential properties rarely if ever even approach the levels necessary for even the most cosmetic of plaster cracking. Engineered structures such as industrial and heavy commercial buildings and underground constructions are able to sustain higher levels of vibration than those applicable to residential type properties by virtue of their more robust design.

31. British Standard 7385: Part 1, 1990 and Part 2, 1993 discusses the resistance of structures to blast induced vibration and specifies guide values to preclude damage to various buildings types from blast induced ground vibration.

Prediction

32. Variations in instantaneous charge weights at any specific site relate closely to variations in vibration magnitude. It is this parameter that, together with distance from the blast, that forms the basis of vibration prediction.

33. The accepted method of prediction is to plot measured peak particle velocity values against a scaled distance value for each measurement. The scaled distance value is taken as the blast/receiver separation distance divided by the square root of the maximum instantaneous charge weight of explosive in the shot from which the measurement was taken.

34. When a number of such values are plotted on logarithmic axes a straight line relationship is seen to exist for any particular site. Taking vibration recordings at increasing separation distances from a blast ensures that geological effects are covered and if a number of blasts at any one site are monitored then variation between blasts can also be quantified.

35. Vibration transmission may not always be the same in all directions from a blast site. Vibration recordings may be required therefore, in different directions in order to quantify any such differences. It is the upper confidence level, generally taken as 95%, that forms the basis of most vibration regulations.

Effects of Geology

36. Once the vibration is generated at source it is the geology of the intervening ground that will largely determine the manner in which the vibration is transmitted and hence the predominant characteristics of the vibration including its magnitude at any given distance. An important factor in this regard is the propagation velocity which is an indirect measure of geological properties that affect the rate of decay of vibration. The more competent and less weathered the rock mass then the greater is the propagation velocity in any particular rock type. However, variations in propagation velocities within one rock type and between rock types can be significant, hence the importance of site specific vibration measurements.

air overpressure

37. Air overpressure is energy transmitted from the blast site within the atmosphere in the form of pressure waves. As these waves pass a given position, the pressure of the air rises very rapidly then falls more slowly then returns to the ambient value after a number of oscillations. The

maximum excess pressure in this wave is known as the peak air overpressure, generally measured in decibels linear (dB).

38. The pressure waves consist of energy over a wide range of frequencies, some of which are audible and hence may be sensed in the form of noise, but most are at inaudible frequencies of less than 20 Hz. This relatively low frequency component can be sensed by people in the form of a pressure wave known as concussion. The noise and concussion together is known as air overpressure.

Measurement

39. Measurement of air overpressure levels must always be undertaken with microphones that have an adequate low frequency response in order to fully capture the dominant low frequency components.

40. Practical problems may arise when measuring air overpressure under windy conditions since wind is itself a pressure variation that may mask the blast generated pressure wave.

41. It is also the case that due to the unpredictable and uncontrollable effects of prevalent atmospheric conditions, the location at which the maximum air overpressure is expected cannot be determined with any degree of accuracy. Hence, demonstration of compliance with any specific air overpressure limit is not a practical possibility.

42. The routine measurement of the air overpressure level together with groundborne vibration is clearly of great importance in terms of both public relations and a clearer understanding of any environmental disbenefit of an operator's blasting practices.

Human Response

43. Human reaction to a blast event will be in response to the resulting effects of both ground and airborne vibration and in particular the combined effects that these exhibit within a property when secondary noise effects can be readily induced by relatively low values of air overpressure or by groundborne vibration alone.

44. Routine blasting operations regularly generate air overpressure levels at the closest of adjacent property of around 120 dB. The pressure equivalent of 120 dB will be generated by a constant wind velocity of just 5ms⁻¹ (Beaufort force 3, gentle breeze) whilst an air overpressure of 130 dB is equivalent to a wind velocity of less than 8ms⁻¹ (Beaufort force 4, moderate breeze). Such magnitudes will be perceived by individuals although they are entirely safe.

45. The response of an individual to any such event is dependent upon the same factors as that of groundborne vibration with the understanding of the phenomenon through public relations and the attitude of the operators being of utmost importance.

Effects of Topography

46. Wavelength differences associated with this frequency range mean that any effects of topography are likely to be more pronounced for the audible component of air overpressure rather than the concussive component. Thus a topographic feature forming a barrier between the blast site and the receiver may reduce the blast's audible component but have relatively little effect upon the concussive component. Whilst any reduction in the audible nature of an air overpressure wave is to be welcomed such energy is relatively low within the overall pressure wave and, therefore, barriers are seen to have little effect unless they are substantial. For example, man made features such as acoustic fences and earth amenity bunds commonly placed along a site's boundaries would not be expected to reduce to any significant degree the value of air overpressure received off site, although they are beneficial in reducing noise from other sources. More substantial barriers such as a series of quarry faces can reduce air overpressure values when blasting at depth.

Effects of Meteorological Conditions

47. Because air overpressure is transmitted through the atmosphere, meteorological conditions such as wind speed and direction, temperature, cloud cover and humidity will all affect the intensity of the air overpressure experienced at a distance from the blast site.

48. If a blast is detonated in a motionless atmosphere in which the air temperature is constant, then the air overpressure intensity will decrease purely as a function of distance and will, once outside of the immediate vicinity of the blast, reduce by 6 dB as the distance from source doubles.

49. Such conditions are very rare and it is more usual for temperature to vary with altitude in a fairly complex and changing manner. Winds are also invariably present at differing velocities and directions at differing altitudes. The overall result is that the nominal 6 dB reduction may be greater in some directions from the source and less in others.

50. Given sufficient meteorological data concerning the relevant parameters of wind speed and direction and air temperature, and how these vary with altitude, it is possible to predict these expected increases or decreases. In practice, however, the data is obtained from meteorological stations at some distance from the blast site and at some time before the blast is to be detonated. As such, it is therefore doubtful whether the data will be relevant at the specific site and at the proposed time of blasting, the situation being further complicated by the variable Scottish weather.

51. Minimising air overpressure at source, such that, even under unfavourable weather conditions, all such energy is within acceptable criteria at distance, remains the best practicable approach. It is an approach that all surface mineral sites are obliged to follow under the provisions of The Quarries Regulations 1999.

Effects of Blast Design

52. There are five principal sources of air overpressure from blasting at surface mineral workings:

- The use of detonating cord which can produce high frequency and hence audible energy within the air overpressure spectrum.
- Stemming release, seen as a spout of material from the boreholes, gives rise to high frequency air overpressure.
- Gas venting through an excess of explosives leading to the escape of high-velocity gases, give rise to high frequency air overpressure.
- Reflection of stress waves at a free face without breakage or movement of the rock mass. In this case the vertical component of the ground-vibration wave gives rise to a high-frequency source.
- Physical movement of the rock mass, both around the boreholes and at any other free faces, which gives rise to both low and high-frequency air overpressure.

53. Detonating cord should be used as sparingly as possible, and any exposed lengths covered with as much material as possible. Just a few feet of exposed cord can lead to significant amounts of audible energy and, hence, high air overpressure levels. Stemming release can be controlled by detonation technique, together with an adequate amount of good stemming material. Drill fines, while readily available, do not make good stemming material. The use of angular chippings is better. It should be noted however that detonation cord and stemming release have been virtually eliminated with the use of in hole initiation techniques.

54. Gas venting results from overcharging with respect to burdens and spacings or, perhaps, a local weakness within the rock, and is also typified by the occurrence of fly rock. Its control is essential for economic and safe blasting, and is considerably aided by accurate drilling and placement of charges, together with regular face surveys.

noise

55. Although the majority of energy generated within the atmosphere from any surface mineral blasting will be of a sub-audible nature, there will also be a component that is audible, i.e. at frequencies greater than 20 Hz, and as such can be heard as noise and measured in terms of dB(A).

see PAN 50 Annex A: The Control of Noise at Surface Mineral Workings and PAN 56 Planning and Noise

56. Peak levels from blasting are comparable to the sort of levels typically generated at properties by passing cars, etc., only in the case of blasting the noise would exist for around a second and occur relatively infrequently. It is because of this very brief duration and its infrequent occurrence that blast noise is rarely measured in terms of dB(A) but rather looked at as part of the air overpressure generated and measured by the more meaningful parameter of dB.

57. If the use of exposed detonating cord is avoided the characteristic noise of a blast is no longer a sharp crack but rather a dull thump. This is partly due to the detonating sequence and partly due to natural energy dissipation and reduction. Whilst some of the noise perceived by a neighbouring resident would be directly from the blast itself, the lower frequency components of the air overpressure might well induce secondary rattling of windows and ornaments within a property which could augment the overall effect.

58. Thus in terms of noise control or reduction the care and attention to blast design and subsequent implementation, including initiation, necessary for the control of air overpressure is equally applicable to noise.

dust

59. Dust from blasting activities can arise from two potential activities, namely the drilling of the boreholes and from their subsequent detonation.

see PAN 50 Annex B: The Control of Dust at Surface Mineral Workings

60. Drill rigs have potential for the emission of significant quantities of dust if the waste air that is vented to atmosphere is not first filtered. Such dust suppression techniques are commonplace and hence the relatively high potential for dust emissions from this source is rarely if ever realised.

61. Detonation of the explosives results in either ground heave in the case of opencast coal site blasting or the formation of a rock pile in the case of typical quarry blasting. Both involve the generation of dust depending upon specific ground conditions.

62. Mitigation measures can involve the bagging and removal from the blast zone of the drill returns. An adequate quantity and quality of stemming material is also of importance in order to prevent the explosives' rapidly expanding gases from ejecting such material from the blast holes and acting as a source of dust generation. This latter precaution will also reduce the potential air overpressure and noise generation associated with a blast event. In practice, however, these measures can only be partially effective in reducing overall dust emissions that originate primarily from within the previously undisturbed rock mass.

flyrock

63. Flyrock is the unexpected projection of blast debris beyond the designated danger zone as defined by the person who prepares the specification. This may involve projection beyond the site boundary in which case the incident must be reported to the Health and Safety Executive.

Causes of Flyrock

64. The most common causes of flyrock include:

Insufficient Burden - When there is insufficient burden or stemming on the column of explosive then the potential for flyrock exists, as the energy released from the explosive is likely to be greater than that required to solely fragment the rock mass in its immediate locality resulting in excess energy available to project rock debris beyond the danger zone.

Insufficient Training - The Quarries Regulations 1999 state that it is the operators responsibility to ensure that those dealing with explosives are trained to a suitable standard. There is already greater awareness of the need for proper training and this has been reflected in a reduction in the number of flyrock incidents.

Inadequate Specification Factors - The Quarries Regulations 1999 give the factors to be considered when designing blasts and all should be taken into account.

Hole Deviation - This can be in the form of drilling at the wrong angle in any direction resulting in either reduced toe burden or toe charges in consecutive holes being too close together giving too high a concentration of explosives at one point.

Incorrect Delay Sequence - Care must be taken to ensure the correct delay sequence is used. Delay periods must be chosen such that underburdening of subsequent shot holes does not occur.

Cavity - It has to be recognised that in certain rock formations, such as some limestones, cavities may exist and are a potential problem since if inadvertently filled with explosive they can give rise to a local concentration of explosives that is too great with respect to the surrounding rock mass or burden. This can only be countered by careful checking of the explosive column length during loading to ensure the explosive is not filling a cavity. Cavities provide a greater source of danger when using bulk loading explosive systems due to the faster loading rate employed.

Explosives in the Stemming Line - Explosives can be introduced into the stemming line either deliberately in an attempt to break hard top bands or accidentally usually as a result of employing bulk loading methods. In both cases any excess of energy from the rapidly expanding explosives gases may result in debris projection.

Unforeseen Geological Weakness - This is the most difficult to detect and counter and is often the main cause of flyrock.

Weathered or Loose Rock in the Stemming Line - Extra care must always be taken when blasting operations take place in these conditions.

Prevention of Flyrock

65. Flyrock can never be completely eliminated. The number of incidents however can continue to be reduced by ensuring blasts are carried out exactly to the specification. Under The Quarries Regulations 1999 a written specification must be prepared for each blasting operation to ensure, so far as is reasonably practicable, that when blasting occurs it will not give rise to danger. The specification should take account of all possible causes of flyrock. Should deviations to the specification occur then management must be informed and be aware of the potential hazard. Training of all personnel is essential to ensure these incidents are minimised. Work carried out to date on methods to reduce flyrock, such as buffer blasting and the use of blasting nets, has been limited and inconclusive. Planning authorities can seek advice from the Health and Safety Executive if they are concerned at the risk of flyrock.

Risk Based Approach to Flyrock

66. When considering planning proposals involving blasting the possibility of flyrock should be taken into account especially if property or public access is nearby. However, it is not reasonable to sterilise significant areas of land on the remote possibility that a flyrock incident may occur at some time in the future. Risk assessment and its growing acceptance as a safety management tool means that flyrock danger zone distances can be based on acceptable risk levels rather than the potential consequences of infrequent events. Methods of working should be designed and agreed at the planning stage. This should include direction of working, face height and face angle together

with expected borehole diameters, burdens, spacings, explosive type and initiation system if possible.

limitations of blasting

67. Virtually all aspects of blast design can affect the performance and efficiency of a blast and therefore the resulting vibration levels generated at source. The maximum instantaneous charge weight of explosive, that is, the maximum explosive charge detonated at any precise instant of time, has the greatest effect upon vibration levels for a given optimum design of blast. However, this parameter cannot be considered alone because it is connected to most other aspects of blast design, the relationship being expressed by the term blast ratio. The blast ratio is a measure of the amount of work per unit of explosive, measured for example in tonnes of rock per kilogram of explosives detonated (tonnes/kg), and is dependent upon virtually all aspects of a blast's design, for example, hole diameter and depth, burden, spacing, explosives, loading density and initiation technique.

68. Generally the optimum blast ratio at any specific site not only gives rise to optimum fragmentation but also to the minimum ground borne vibration for the specific blast under consideration. If less than the optimum amount of explosive is utilised then an increase in ground vibration occurs, because the lack of sufficient explosive energy required in order to efficiently fragment the rock results in an increase of energy transmitted to the surrounding ground largely in the form of vibration. Thus the most useful and practical method of reducing ground vibration levels in order to meet vibration specifications is to reduce the maximum instantaneous charge weight of explosive detonated in any blast event whilst maintaining the blast ratio through reductions in the other relevant parameters of blast design such as loading density, burden and spacing.

69. Typically each hole within a blast is detonated individually by the use of detonators with inherent delay periods. Thus the maximum instantaneous charge is usually the maximum amount of explosive on any one specific delay detonator in any one blast hole. A reduction in instantaneous charge weight may be obtained by reducing the total amount of explosive placed into the boreholes drilled for the blast, typically from 10 to 30 boreholes depending on the specific site conditions.

70. Deck loading may be employed whereby a relatively small amount of the column of explosive within the boreholes is replaced by inert stemming material in order to separate the explosive into two discrete decks. If each of these decks is then initiated with detonators of differing inherent delays then the maximum instantaneous charge may be virtually halved. Any number of decks within a blast hole are possible in theory, being limited only by the requirements of the given blast ratio and the need for sufficient stemming between the decks so that the simultaneous detonation of the separate charges is prevented. Thus, there are relatively few purely technical limitations on blasting operations in the sense that maximum instantaneous charges can be reduced in order to reduce the resulting ground vibration levels as sensitive locations are approached. In practice several important considerations must always be recognised:

- Maximum instantaneous charges are, in the absence of any restrictions, typically of the order of 20 to 40 kg in opencast coal site blasts and 100 to 200 kg at quarries. Whilst reductions in instantaneous charges by factors of 2 to 3 by means of decking and/or reductions in hole depths and diameters may be practicable on certain sites, depending upon the initial blast designs, these reductions are only possible whilst maintaining the require blast ratio. In practice this has the effect of significantly increasing the number of boreholes required in order to dislodge the same volume of material. This increase will in turn significantly increase the drilling and detonator costs.
- Even when using optimum blast designs it is the case that blasting as a means of rock removal is relatively expensive at both quarries and coal sites. Because of this, any increase in blasting costs due to the factors above readily renders blasting operations uneconomic, albeit technically feasible.
- The economics of surface mineral working are largely related to a given rate of material removed by blasting so any significant decrease in the number of holes drilled per blast will also tend, in practice, to increase the number of blasts needed to fragment the same

volume of material. This use of smaller, more frequent blasts leads to smaller but more frequent vibration impacts. Whether this results in a perceived improvement in environmental intrusion will depend upon whether it is the magnitude of the events or the frequency of their occurrence that is of most concern to a potential complainant. In each case the balance between these factors needs to be assessed by discussion with interested parties.

- Also of importance is the effect that reductions in burdens and spacings may have upon the variability and the safety of blasts.

conditions

71. Conditions and their wording should be a matter for discussion between the planning authority and site operator and will depend upon the specific details of each individual site. These details will include the type of mineral being worked and the form of blasting operation required for its economic recovery. Conditions should be in accordance with SODD Circular 4/1998. In all cases, it will be necessary to ensure that planning conditions accord with good and safe practice under the Quarries legislation. Advice can be sought from the Health and Safety Executive before conditions to control blasting are imposed.

see NPPG 16 Opencast Coal and related Minerals, paragraphs 53-60, SODD Circular 34/1996 Annex L and SODD Circular 4/1998

72. It is recommended practice that conditions should provide for:

- the unacceptable days and times of blasting operations
- the allowable level of ground vibration
- a scheme by which air overpressure is controlled
- a scheme of vibration monitoring so that compliance with the set limits can be demonstrated.

73. All planning conditions should have due regard to the requirements of The Quarries Regulations 1999. Accordingly, specific aspects of blast design, such as the number of boreholes or the amount of explosives to be used, should not be included in the blasting conditions. Blast design criteria must always be the direct responsibility of the site operator as defined by The Quarry Regulations 1999. Flyrock control and warning systems are also integral parts of these Regulations and as such are not appropriate subjects of blasting conditions.

74. Conditions should, wherever possible, state the desired objectives rather than the methods by which they can be achieved. One exception to this is in respect of air overpressure, the off-site magnitudes of which are difficult to always accurately control or predict due to atmospheric conditions. Accordingly an alternative approach is suggested whereby a scheme of control of air overpressure is detailed by the operator for subsequent agreement with the planning authority.

75. When formulating conditions the following points require consideration.

Days and Times of Blasting Operations

76. Whilst specific blasting hours should be a matter for discussion between the planning authority and operator they should allow, where possible, for blasting to take place at regular times within specified periods on Mondays to Fridays. The need for Saturday morning blasting should be given separate consideration and blasting would not normally be allowed on Saturday afternoons, Sundays, Bank Holidays or National Holidays.

77. In the event of an emergency, any conditions should be able to be relaxed, in which case the planning authority should be notified immediately of the details of the event.

78. A public road adjacent or near to a surface mineral workings may need to be temporarily closed during blasting operations, for instance when the public road comes within the designated

danger zone. If this is the case, full consideration should be given to the impact on traffic caused by the temporary road closure. The relevant roads authority should be consulted to determine what traffic management measures are necessary. Restricting blasting to set times will allow the public to plan journeys and avoid any temporary road closures.

see PAN 50 Annex C: The Control of Traffic at Surface Mineral Workings, paragraph 97-99

79. An example of a condition controlling blasting times is as follows:

No blasting shall be carried out on the site except between the following times [1000 and 1200 hours] and [1400 and 1600 hours] on Mondays to Fridays and [1000 and 1200 hours] on Saturdays.

There shall be no blasting or drilling operations on Sundays, Bank Holidays or National Holidays.

The above condition shall not apply in cases of emergency when it is considered necessary to carry out blasting operations in the interests of safety. The planning authority shall be notified in writing immediately of the nature and circumstances of any such event.

Allowable Ground Vibration Levels

80. Allowable ground vibration levels should be specified in terms of peak particle velocity measured in millimetres per second. The recommended criterion is the maximum of 3 mutually perpendicular directions. It should be noted that in order to demonstrate compliance with BS6472, concerning perception, that additional recordings may be necessary within a building at a point of disturbance to an occupant. (see paragraph 97)

81. In determining the precise level of peak particle velocity it should be recognised that imperceptibility is not a realistic criterion, but that a limit should always be chosen to minimise groundborne vibration according to good practice and safe and efficient blasting operations. As such, the individual circumstances of a particular site must be considered. Specified values should be compatible with current guidance on this matter given within the relevant British Standards publications, namely, BS 6472, 1992 concerning perception and BS 7385, Part 2: 1993 concerning the likelihood of damage.

82. In determining the specific time period, consideration should be given to the anticipated frequency of blast events in order that a representative number can be assessed. It may also be necessary to consider what time period would be representative of any site variations in blast locations and/or design where appropriate.

83. In order to be able to assess compliance with the 95% probability criterion, the number of blasts considered should ideally be 100 or greater. However, in practice it would be unreasonable to extend the time period greater than 12 months before an assessment could be undertaken even if the number of events is relatively small. Blasting within opencast coal sites is within specific cuts or linear areas of a site which progress across the excavation area relatively quickly compared with the progress of quarry faces. Hence, a suitable time period for an opencast coal site may be that time typically taken for any one cut to be fully worked. A minimum time period of 3 months would generally be considered as sufficient to be representative of blasting variations within both opencast coal sites and quarries.

84. The values chosen should recognise the fact that blasts in practice must be designed so that the intended level of 95% confidence is rarely approached or exceeded. In theory therefore, blasts must be designed for mean or average vibration values of around half of the 95% confidence level. In practice, more values will in fact be generated below this average value.

85. Once the threshold of perception is exceeded, the likelihood of complaints is largely independent of vibration magnitude but greatly influenced by the relationship between an operator and the local community.

86. Generally, individual blasts should not exceed 12 mms ⁻¹. Average levels should not exceed 10 mms ⁻¹, and usually will not be below 6 mms ⁻¹ in 95% of all blasts. These levels conform with the BS 6472, 1992 and BS 7385, Part 2: 1993.

87. Whilst it is recognised that under exceptional circumstances it may be appropriate that level are set beyond the range of between 6 to 10 mms ⁻¹ such circumstances should be carefully examined because levels greater than this may give rise to a likelihood of damage at properties. Levels lower than the recommended range may well, in practice, result in a greater number of blasting events in order to produce the same extraction rate which could be environmentally counterproductive.

88. Lower levels may need to be considered in proximity to hospital operating theatres or precision laboratories where delicate tasks or the use of sensitive equipment may coincide with blast times. In determining the permitted vibration levels detailed consideration should be given to any such potential blasting constraints. A fully reasoned justification should be given by a planning authority when they impose a condition requiring vibration levels outside the recommended range.

89. Historic Scotland should be consulted when it is considered that blasting at a surface mineral working may affect a category A listed building or its setting or the site of a scheduled monument or its setting. If necessary vibration levels at historic structures may be set below the recommended range. A condition could require that monitoring of a historic structure is agreed to the satisfaction of the planning authority in consultation with Historic Scotland. This might include a thorough survey of the building, recording width, length and breadth of all defects before commencement of blasting and continued monitoring of defects during blasting operations, until such time as monitoring indicates that no damage has occurred due to blasting.

90. An example outline of a condition limiting ground vibration follows:

Ground vibration as a result of blasting operations shall not exceed a peak particle velocity of [6 mm ⁻¹] [10 mm ⁻¹] in 95% of all blasts measured over any period of [6 months] and no individual blast shall exceed a peak particle velocity of [12 mm ⁻¹] as measured at vibration sensitive buildings. The measurement to be the maximum of 3 mutually perpendicular directions taken at the ground surface at any vibration sensitive building.

Limiting the Number of Blasts

91. Occasionally permissions include a limitation as to the number of blasts permitted on a daily or weekly basis, typically varying from one or two blasts per day to one or two blasts per week. With the adoption of suitable site specific vibration criteria such a condition is unnecessary.

Vibration Sensitive Buildings

92. Planning authorities and mineral operators should consider the effects of ground vibration on vibration sensitive buildings. A vibration sensitive building being any building occupied by a person or persons either on a regular or irregular basis as a form of dwelling, workplace, meeting place, etc (for example, residential property, school, offices, industrial premises, church, village hall). Such occupation need not necessarily occur at the time of the blasting event.

Scheme of Air Overpressure Control

93. A scheme which details the intended methods to be employed in minimising air overpressure from blasting operations is recommended in preference to limit values, as previously advised in PAN 50 page 15. This is because of the nature of this phenomenon and because conditions that are intended to control its effects need to be both precise and enforceable. Such a scheme would need to be detailed by the operator and agreed with the planning authority.

94. Although air overpressure can be controlled to a great extent at source by careful attention to blast design and implementation, once detonation occurs the prevailing atmospheric conditions play a significant role in determining air overpressure values at distance from the blast site.

95. A scheme of air overpressure control should address:

- the adequate confinement of all explosive charges through sufficient quantity and quality of stemming material;
- the adequate confinement of all charges by means of an accurate face survey and subsequent judicious placement of explosive charges;
- the precautions to be taken in areas known to exhibit weaknesses in the ground;
- the detonation techniques preferred, including the practicality of prohibiting the use of surface lines of detonating cord;
- the practicality of prohibiting the use of secondary blasting; and
- the procedure to be followed in the event of a misfire.

96. An example of a condition requiring that a scheme of air overpressure control is submitted for approval of the planning authority is as follow:

Prior to the commencement of blasting operations details of the methods employed to minimise air overpressure from blasting operations shall be submitted to the planning authority for written approval. All blasting operations shall take place only in accordance with the scheme as approved or with such subsequent amendments as may receive the written approval of the planning authority .

Scheme of Vibration Monitoring

97. The precise requirements of any scheme for the monitoring of blast induced vibration should be a matter of discussion between the planning authority and operator. Requirements will be site dependent and must take into account local conditions. Any such scheme should consider:

- The location and number of monitoring points

Usually the closest vibration sensitive building to current blasting operations would be the preferred monitoring location. Where blasting takes place in more than one area within a site then more than one monitoring location may be necessary. It may also be appropriate to monitor at other vibration sensitive locations that are not the closest to the blast site.

In some situations access to a vibration sensitive building may not be practicable. In this case, consideration should be given to the selection of a location away from the building in a general line with the area to be blasted and at which monitoring could be regularly undertaken. Such locations may be at or just within the site boundary.

- The type of equipment to be used and the parameters to be measured.

The measurement of vibration should be undertaken using specialist monitors designed for the purpose of blast vibration monitoring. Such instrumentation, termed seismographs, should be capable of recording both ground and airborne vibration. Ground vibration should be recorded in terms of peak particle velocity in millimetres per second and in 3 mutually perpendicular directions. Airborne vibration should be measured in terms of decibels (dB) or on a linear scale in terms of pounds per square inch (p.s.i.).

- How often the measurements are required to be taken.

It would generally be the case that all blasts are monitored in order to be able to demonstrate compliance with a vibration limit. In a situation where measured vibration levels are relatively low when compared with the site limit it may be appropriate that only a representative sample of blasts are monitored over a given time period. In all cases the scheme should precisely define what is required.

- The method by which such data are made available to the planning authority.

The results of monitoring should be freely available to the planning authority. Typically the results would be kept at the site and made available for inspection by the planning authority at all reasonable times with copies being supplied to the planning authority upon request.

- The method by which such data are used in order to ensure that the site vibration limit is not exceeded and to mitigate any environmental effects of blasting.

Procedures may be specified if recorded values exceed an agreed level. Typically these procedures would involve notification of the planning authority of the event together with an assessment of its implication with respect to future blasting activity and the site's vibration limit.

98. An example outline of a condition requiring that a scheme of vibration monitoring is submitted to the planning authority for approval is as follows:

Prior to the commencement of any blasting operations a scheme for the monitoring of blasting including the location of monitoring points and equipment to be used shall be submitted to the planning authority for written approval. All blasting operations shall take place only in accordance with the scheme as approved or with such subsequent amendments as may receive the written approval of the planning authority.

complaints procedures

99. The role of the planning authority and environmental health officer can be paramount in influencing the level of concern expressed about blasting operations. Generally viewed as independent by a site's neighbours, the planning authority and environmental health officer should be in the position of being able to investigate such concerns thoroughly. If concern has been expressed, after having evaluated the situation they should be able to explain the significance of the vibration received at property in comparison with site conditions and recognised standards. If appropriate they may be in a position to enforce conditions.

see NPPG4 Land for Mineral Working

100. The following can facilitate this role:

- Maintain regular contact with relevant site personnel and the local community, preferably by means of a site liaison committee.
- Liaise with the site operator concerning their complaints procedure and their site monitoring procedures.
- Establish the procedures to be followed in the event of complaints received by the local authority.

101. A complaints procedure should include the following:

- A log of the complaint in a specific register to cover:
 - - the date and time that the complaint was received;
 - the nature of the complaint;
 - the name, address and telephone number of the complainant; and
 -
 - subsequent follow-up details.

- The complainant should be contacted as soon as is practicable so that a meeting to discuss the complaint can be arranged.
- Have due regard to the fact that site blasting activities may be wrongly identified as the prime source of concern. This may result either from the source of vibration being wrongly identified by the complainant or from a general dissatisfaction with the site due primarily to other reasons.
- Discuss the complaint with the site operator to explore the possibility of minimising all vibration irrespective of whether or not the site conditions are being met.
- Inspect site records to ensure compliance with all blasting conditions. In the event of non-compliance, discuss with the operator the methods by which he intends to conform in future. Consider the necessity for enforcement action.
Arrange to monitor subsequent blast event or series of events as appropriate. In some cases it will be adequate to view the operators results of vibration monitoring. In other cases local authority staff may wish to attend the monitoring to check results. Some local authorities have the necessary equipment and skills to carry out monitoring themselves, others get professional assistance when needed. It is a matter for the planning authority to decide what action to take. In the event of unattended monitoring it is advantageous if the instruments used can generate a time history of any vibration event.
- After monitoring, immediately show the results to the complainant and relate all results to the relevant site conditions, the relevant British Standards and Government guidelines, and every day occurrences.
- A written explanation of the situation may be an appropriate form of reassurance.
- In the case of persistent complaints consider the involvement of complainants by means of a regular log of perceived events which will be discussed upon completion with the site operator.

102. The correct monitoring and recording of vibration levels from blasting activities is an essential part of maintaining good public relations and in ensuring an operator's compliance with blasting conditions. The onus for carrying out such monitoring should fall on the operator, with the results being made available to the planning authority. Conditions are not the appropriate mechanism to outline the detailed requirements for a scheme of monitoring. Instead a condition should specify that a scheme of monitoring should be submitted for the approval of the planning authority. Detailed requirements for a scheme of monitoring can be agreed as part of a Section 75 Agreement. Any planning agreements should comply with SODD Circular 12/1996.

environmental impact assessment

103. The Environmental Assessment Directive (85/337/EC) has been amended by Directive 97/11/EC which has been transposed into Scottish planning law by the Environmental Impact Assessment (Scotland) Regulations 1999 (SEDD Circular 15/1999). Under the new regulations an Environmental Impact Assessment will be mandatory for proposed quarries and opencast mining where the surface area of the site exceeds 25 hectares. Smaller sites will continue to be considered for Environmental Impact Assessment under Schedule 2. It also states that changes or extensions to Schedule 2 projects already authorised which may have significant adverse effects on the environment are, themselves, considered to be Schedule 2 projects. Guidance on 'Review of Old Mineral Permissions and Environmental Impact Assessment' can be found in SODD Circular 25/1998.

see PAN 58 Environmental Impact Assessment and SODD Circular 25/1998

104. The effects of blasting could be among the issues to be addressed in the assessment. The planning authority may wish to specify that the assessment includes blasting trials in order to establish the actual ground vibration and air overpressure levels and their environmental impact. However, in some instances it may not be appropriate to carry out full scale test blasting. In such cases data from a comparable surface mineral working may be helpful in understanding the effects from blasting.

105. The planning authority may also wish to specify that the assessment addresses the impact of ground vibration and air overpressure on wildlife. Bodies such as Scottish Natural Heritage, Scottish Wildlife Trust and the Royal Society for the Protection of Birds can be valuable sources of information and advice on wildlife. Planning authorities and operators should be aware of the protection provided by the European Community Habitats and Bird Directives.

see NPPG 14 Natural Heritage and SOEnvD Circular 6/1995 Habitats and Birds Directive

development plans

106. Development plans should provide clear guidance to mineral operators and the public as to the consideration that will be relevant in assessing planning applications. This will include policies to ensure protection of the environment. Standards should therefore be identified which are judged necessary to control the environmental effects of blasting. Mineral operators should be guided by this as to the need to mitigate blasting disturbance and incorporate appropriate controls within any proposals for mineral extraction.

see NPPG4 Land for Mineral Working

107. In preparing their development plans, planning authorities should have regard to the need to protect communities and areas prized for their environmental, historic, recreational or amenity value from the environmental effects of blasting. In drawing up policies in their development plans, planning authorities will wish to consider the advice in this Annex on the steps that might reasonably be taken to control blasting and also the approach to setting blasting controls that will be incorporated in planning conditions. Where the planning authority proposes to include development plan policies that go beyond the British Standards a fully reasoned justification should be provided.

implementation and review

108. This Annex provides the basic framework for the consideration of blasting at surface mineral development proposals and for the monitoring and control of operations.

109. The Annex has been based on the best information currently available. It may need updating in the future to reflect changes in technology and environmental standards, and in the light of any future relevant research findings.

110. This advice for controlling the environmental effects of blasting should at all times be considered in the light of the requirements of the appropriate legislation, specifically The Quarry Regulations 1999 must always take precedence.

note

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summary: good practice on blasting

Planning authorities should:

- Provide guidance in development plans to mineral developers on the appropriate development control criteria for blasting that will be used in determining planning applications for mineral development.

- Consider the need to agree or specify planning conditions relating to:
 - The allowable level of ground vibration to meet the 95% confidence level monitored over an appropriate period;
 - A scheme by which air overpressure is controlled;
 - A scheme of vibration monitoring so that compliance with set limits can be demonstrated; and
 - The unacceptable days and times of blasting operations.
- Consider the need for an Environmental Impact Assessment and whether blasting should be amongst the issues it addresses.
- Maintain regular contact with relevant site personnel and the local community, preferably by means of a site liaison committee.
- Liaise with the site operators concerning their complaints procedure and their site monitoring procedures.
- Establish the procedures to be followed when the local authority receives complaints.
- Ensure monitoring and recording of vibration levels from blasting activities to maintaining good public relations and ensure an operator's compliance with blasting conditions. Where a planning authority has no access to monitoring equipment they may consider attendance at monitoring by the site operator.

Mineral operators should:

- Ensure that the blast area is accurately surveyed and recorded according to The Quarries Regulations 1999.
- Ensure that the correct design relationship exists between burden, spacing, and hole diameter.
- When bench blasting choose the correct burden with due regard to the local geological conditions and the face survey information.
- Drill accurately in order to maintain the intended blast pattern and keep subdrilling to the minimum required.
- Ensure there is an adequate dust collection system for each drill rig.
- Bag and remove all collected dust from the immediate blast zone.
- Make maximum use of existing free faces.
- If necessary, revise the intended blast design following inspection of the survey data.
- Ensure that the maximum amount of explosive on any one delay interval, the maximum instantaneous charge, is optimised by considering:
 - reducing the number of holes per detonator delay interval
 - reducing the instantaneous charge by in-hole delay techniques
 - reducing the bench height or hole depth
 - reducing the borehole diameter
- Ensure that the optimum blast ratio is maintained in any changes of blast design.
- Ensure that the detonator delay sequence optimises the internal free faces developed during the detonation sequence, particularly in multiple row blasting and in corners.

- When practicable ensure that the direction of detonation is away from the nearest vibration sensitive location.
- Have due regard for any local weaknesses in the strata, including back break from any previous shot, clay joints, and fissured ground.
- If loading explosives through fissured or broken ground, or through cavities of any kind, consider only the use of pre-packaged explosives and/or check the hole depth regularly during loading.
- Whenever possible the use of unconfined charges should be avoided; also consider prohibiting surface lines of detonating cord and secondary blasting.
- All surface detonators and explosives should be adequately covered with suitable material.
- Stemming material should be of sufficient quantity and quality to confine adequately all explosives upon detonation. A coarse stemming material such as angular chippings should be considered for use. Drill fines should not be used.
- Consider bottom initiation in preference to top initiation.
- Misfire procedures should have due regard to under-burdened charges.
- If air overpressure levels are a problem give consideration to a reduction in the area to be blasted.
Blast at regular times, ideally on the hour.
- Regularly monitor the ground and airborne vibration generated by blasting events so the information can be employed in any necessary modification of future blast designs.
- Maintain good public relations with those who live and work near the blasting site.
- Always attempt to minimise the resulting environmental effects of blasting operations and recognise the fact that the perception of blasting events occurs at levels of vibration well below those necessary for the possible onset of the most cosmetic of damage; but nevertheless at levels that can concern neighbours.
- Be aware that relatively small changes in blast design can produce noticeable differences in environmental emissions and that it is very often in response to changes in these emissions rather than their absolute value that complaints may be made.

glossary of technical terms

Air Overpressure: A pressure wave in the atmosphere produced by the detonation of explosives. Consists of both audible (noise) and inaudible (concussion) energy.

Bench blasting: A method of blasting in quarries and opencast sites by means of steps or benches with holes positioned parallel to the bench face.

Blasting nets: Nets manufactured usually from heavy section steel mesh which are placed over the blasting area in an attempt to reduce flyrock.

Buffer blasting: The practice of firing a second shot before completely excavating the previous shot. This is usually an attempt to reduce flyrock.

Burden: The distance measured at right angles between a row of holes and the free face, or between rows of holes.

Concussion: The inaudible energy within the air overpressure generated by the detonation of explosives.

dB: Decibel, a unit of measure on a logarithmic scale used to quantify pressure fluctuations such as those associated with air overpressure.

dB(A): Decibels measured within an A weighted frequency curve that differentiates between sounds of different frequency in a similar way to the human ear.

Deck loading: Dividing the borehole to be charged with explosives into two or more sections usually to reduce the instantaneous explosive charge. The space between the separate charges or decks is filled with stemming material.

Drill fines: Material displaced from the borehole during drilling.

Flyrock: The projection of material from the blast site to any area beyond the designated danger zone.

Free face: A rock surface bounded by air.

Frequency: The number of cycles per second of a vibration usually expressed in units of Hertz, Hz.

Maximum Instantaneous Charge Weight: The maximum amount of explosive detonated at any one precise time.

Three Mutually Perpendicular Directions : The three dimensions which particles oscillate in; longitudinal, vertical and transverse. See paragraph 16.

Peak Particle Velocity: A measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second.

Secondary blasting: The blasting of rock which has not been adequately fragmented by the primary blast. Also called plaster blasting.

Stemming: An inert material used to confine or separate explosives loaded into a borehole, typically stone chippings.

Toe: The bottom of a borehole

Toe burden: The distance between the blasthole and the free face measured at the floor of the bench.

Vibration sensitive building: Any building occupied by a person or persons either on a regular or irregular basis as a form of dwelling, workplace, meeting place, etc.

bibliography

Legislation:

Environmental Protection Act 1990

Health and Safety, The Quarry (Explosives) Regulations 1988, SI No. 1930

Health and Safety, The Quarries and Miscellaneous Health and Safety Provisions Regulations 1995, SI No. 2036

Health and Safety, The Quarry Regulations 1999, SI No. 2024. (Came into force on 1 January 2000)

National Planning Policy Guidelines (NPPGs):

NPPG 4 Land for Mineral Working

NPPG 14 Natural Heritage

NPPG 16 Opencast Coal and Related Minerals

Planning Advice Notes (PANs):

PAN 50 Controlling the Environmental Effects of Surface Mineral Workings

PAN 50 Annex A The Control of Noise at Surface Mineral Workings

PAN 50 Annex B The Control of Dust at Surface Mineral Workings

PAN 50 Annex C The Control of Traffic at Surface Mineral Workings

PAN 56 Planning and Noise

PAN 58 Environmental Impact Assessment

British Standards and Guidance:

British Standard 7385: Part 1, 1990, Evaluation and measurement for vibration in buildings. Guide for measurement of vibration and evaluation their effects on buildings

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

British Standard 6472, 1992, Guide to evaluation of human exposure to vibration in buildings (1Hz to 80 Hz)

British Standard 5228: Part 3, 1997, Noise and vibration control on construction sites, Part 3. Code of practice applicable to surface coal extraction by opencast methods.

Circulars:

SODD Circular 26/1994 The Environmental Assessment (Scotland) Amended Regulation 1994

SOEnvD Circular 6/1995 Habitats and Birds Directive

SODD Circular 12/1996 Planning Agreements

SODD Circular 34/1996 Annex L Illustrative Guide to Conditions

SODD Circular 4/1998 The Use of Conditions in Planning Permissions

SODD Circular 25/1998 Review of Old Mineral Permissions and Environmental Impact Assessment

SEDD Circular 15/1999 The Environmental Impact Assessment (Scotland) Regulations 1999

Other Relevant Publications:

The Environmental Effects of Production Blasting from Surface Mineral Workings. (Vibroch Ltd, in association with University of Leeds, Department of Mining and Mineral Engineering and Swift Research Partners, 1998, The Stationery Office, ISBN 0 11 753412 9) This contains a full bibliography of blasting related publications.