BRITISH STANDARD

BS 5228 : Part 5 : 1997

Noise and vibration control on construction and open sites

Part 5. Code of practice applicable to surface mineral extraction (except coal) sites

ICS 17.140.20; 17.160; 91.200

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee B/209, General building codes, to Subcommittee B/209/17, Noise control on open sites, upon which the following bodies were represented:

Association of Consulting Engineers
British Aggregate Construction Materials Industries
British Coal Corporation
British Compressed Air Society
Building Employers' Confederation
Chartered Institute of Environmental Health
Concrete Society
Construction Health and Safety Group
Construction Plant-Hire Association
Department of the Environment (Building Research Establishment)
Department of the Environment (Pollution Control and Waste Directorate)
Federation of Civil Engineering Contractors
Federation of Dredging Contractors
Federation of Piling Specialists
Institution of Civil Engineers
Sand and Gravel Association Limited

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Contents

Foreword

This Part of BS 5228, which has been prepared by Subcommittee B/209/17, covers the control of noise and vibration from surface mineral extraction (except coal) sites, and is a new Part of BS 5228.

The standard refers to the need for the protection of persons living and working in the vicinity of such sites and those working on the sites, from noise and vibration. It recommends procedures for noise and vibration control in respect of surface mineral extraction operations and aims to assist architects, contractors and site operatives, designers, developers, engineers, local authority environmental health officers and planners, regarding the control of noise and vibration.

Noise and vibration can cause disturbance to processes and activities in neighbouring buildings, and in certain extreme circumstances vibration can cause or contribute to building damage.

Noise and vibration can be the cause of serious disturbance and inconvenience to anyone exposed to it and in certain circumstances noise and vibration can be a hazard to health. The Environmental Protection Act 1990 [1] in England and Wales, which has its provisions extended to vehicles and equipment in streets and public open spaces by the Noise and Statutory Nuisance Act 1993 [2], the Control of Pollution Act 1974 [3] in England, Wales and Scotland, and the Pollution Control and Local Government (Northern Ireland) Order 1978 [4] in Northern Ireland, which define 'noise' as including 'vibration' (Section 79(7) of the 1990 Act, Section 73(1) of the 1974 Act and Article 53(1) of the 1978 Order), contain provisions for the abatement of nuisances caused by noise and vibration. Insulation against noise is addressed in the Noise Insulation Regulations 1975 [5] and (Amendment) Regulations 1988 [6], the Noise Insulation (Scotland) Regulations 1975 [7] in Scotland and the Noise Insulation (Northern Ireland) Regulations 1995 [8] in Northern Ireland.

It should be noted that BS 6472 covers the human response to vibration in structures and BS 7385 : Part 1 covers the measurement and evaluation of structural vibration. BS 7385 : Part 2 contains guidance on damage levels from ground borne vibration.

An item dealing with the vibratory loading of structures is being processed within ISO/TC 98/SC/2, *Safety of Structures*. This is being monitored by BSI.

BS 5228 consists of the following Parts.

Part 1 *Code of practice for basic information and procedures for noise and vibration control*
Part 2 *Guide to noise and vibration control legislation for construction and demolition, including road construction and maintenance*
Part 3 *Code of practice applicable to surface coal extraction by opencast methods*
Part 4 *Code of practice for noise and vibration control applicable to piling operations*
Part 5 *Code of practice applicable to surface mineral extraction excluding coal*

BS 5228 : Part 1 is common to all the types of work covered by the other Parts of BS 5228, which should be read in conjunction with Part 1.

Other Parts will be published in due course as and when required by industry.

Attention is drawn to the Control of Pollution Act 1974 (Part III) (Noise), the Environmental Protection Act 1990 (Part III) (Statutory Nuisances and Clean Air), the Noise and Statutory Nuisance Act 1993, the Health and Safety at Work etc. Act 1974 (in Northern Ireland, the Pollution Control and Local Government (Northern Ireland) Order 1978 and the Health and Safety at Work (Northern Ireland) Order 1978), the Noise at Work Regulations 1989, Statutory Instrument 1989, No. 1790 and the Noise at Work Regulations (Northern Ireland) 1990, Statutory Rules 1990 No. 147.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 14, an inside back cover and a back cover.

Introduction

Surface mineral extraction sites can present different problems of noise and vibration control compared with most other industrial activity for the following reasons:

a) operations are to a large extent carried out entirely in the open;

b) activities are of variable duration, varying from a few months to many decades;

c) on completion, surface mineral extraction sites are restored either to their original condition or to an appropriate state after use;

d) a wide variety of activities, employing different types of plant, are carried out on surface mineral extraction sites. The intensity and character of any noise or vibration may vary at different phases of work, at different times and under differing conditions of, for example, topography, geology, climate and methods of operation;

e) minerals can only be worked where suitable resources exist. Resources may be present in close proximity to premises sensitive to noise and/or vibration. Under these circumstances consideration should be given to the need to protect as far as is practicable such premises from the adverse effects of noise and vibration.

Most of the noise from surface mineral extraction sites is generated by excavating plant, earth-moving plant, blasting activities, processing plant and other heavy traffic. Much of this plant is large and powerful but not necessarily noisy. Vibration is generally only associated with blasting activities. Measures to control noise and/or vibration are generally necessary where sites are located in the vicinity of sensitive premises for the benefit of both the public and the industry.

Blasting only occurs at a proportion of surface mineral extraction sites, generally those producing crushed rock. There are particular characteristics of blasting which require specific consideration of noise and vibration issues. Whilst drilling blast holes is associated with intermittent noise, blasting creates noise and vibration both of which are of very short duration, with a frequency of events varying from a small number per year to several times per day, depending on the nature and size of the extraction operation. The lay person often finds it difficult to differentiate between airborne noise and groundborne vibration. Both effects have more familiar parallels, for example, wind and thunder and pneumatic drills.

A wide variety of different minerals is produced in Britain by surface extraction methods. These include natural and crushed sand, gravel and rock (sedimentary, igneous and metamorphic) produced as aggregates for the construction industry. In addition to some of the foregoing, slate, chalk, china clay, ball clay, fuller's earth, silica sands and various other minerals are essential raw materials to other British industries and world markets. The methods of working of each of these different types of mineral varies greatly according to the type of mineral, its geology and location and the end uses for which the mineral is intended. The nature of any impacts from noise and vibration therefore need to be considered in the context of the relevant site specific factors, bearing in mind the general advice contained in this standard.

Code of practice

1 Scope

This Part of BS 5228 gives recommendations on measures for the control of noise and vibration that should be adopted, where they are practicable and economic, to ensure good practice, in order that the community is subject to minimum disturbance from noise and vibration arising from surface mineral extraction.

NOTE 1. This Part of BS 5228 should be read in conjunction with BS 5228 : Part 1.

NOTE 2. Fixed plant, permanent rail heads and other such facilities may be assessed in accordance with BS 4142.

2 References

2.1 Normative references

This Part of BS 5228 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on page 14. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this Part of BS 5228 only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This Part of BS 5228 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this Part of BS 5228, the definitions given in BS 5228 : Part 1 apply, together with the following.

3.1 overburden

The material overlying the mineral or minerals to be extracted, including topsoil and subsoil.

3.2 baffle mound

A temporary dump usually formed from topsoil or subsoil, for the purpose of reducing noise from the site and to provide a visual screen.

3.3 air overpressure

Airborne pressure waves generated by blasting, produced over a range of frequencies including those which are audible and those which are below the lower end of the audible spectrum. It can be quantified either as a pressure or as a level in linear (unweighted) decibels (dB).

3.4 vibration dose value (VDV)

The fourth root of the integral of the fourth power of acceleration in m/s$^{1.75}$ after it has been frequency-weighted, given by the following equation:

$$\mathrm{VDV} = \left(\int_0^T a^4\,(t)\,\mathrm{d}t \right)^{0.25}$$

where

$a(t)$ is the frequency-weighted acceleration;

T is the total period of the day (in s) during which vibration may occur (see also BS 6472 and BS 6841).

4 Legislative background

4.1 General

The principal legislation controlling the use of land for surface mineral extraction in Great Britain is provided by the Town and Country Planning Act 1990 [1] and the Town and Country Planning (Scotland) Act 1972 [2], both of which have been amended by the Planning and Compensation Act 1991 [3].

The primary planning legislation in Northern Ireland is the Planning (Northern Ireland) Order 1991 [4].

Acts of Parliament, rules and orders which are of relevance include the Environment Act 1995 [5].

There is also separate legislation controlling pollution, waste and statutory nuisance, much of which is now contained in the Environmental Protection Act 1990 [6].

4.2 The winning and working of minerals

The relevant planning authorities are given in the following list:

a) England: County councils, metropolitan boroughs, unitary authorities and national park planning boards where appropriate;

b) Wales: The unitary planning authorities and national park planning boards where appropriate;

c) Scotland: The local authority;

d) Northern Ireland: Department of the Environment for Northern Ireland.

The Secretary of State for the Environment is responsible for setting out Government policy on mineral extraction in a range of Planning and Mineral Policy Guidance Notes. MPG 11 *The Control of Noise at Surface Mineral Workings* [7], is of particular relevance to this standard. In Wales general policy is supplemented by Welsh Office guidance. Policy guidance in Scotland is provided by the Scottish Office in National Planning Policy Guidelines (NPPGs) and circulars, and advice on best practice in Planning Advice Guide Notes (PANS). NPPG 4: *Land for Mineral Working* [8], PAN 50: *Controlling the Environmental Effects of Surface Mineral Workings* [9] and the associated PAN 50 annex A: *The Control of Noise at Surface Mineral Workings* [10], are of particular relevance to this standard. The Secretary of State for the Environment and the Secretaries of State for Wales and Scotland all have powers as defined by the legislation in relation to the submission of planning applications, determination of appeals and in respect of development plans.

Most minerals in Britain are privately owned and are worked by commercial operating companies. Sometimes, however, ownership of the land is divorced from the rights to extract the mineral. Mineral extraction, as a form of development, requires planning permission in order to be undertaken; guidance on the procedures being contained within MPG 9 *Planning and Compensation Act: Interim Development Order Permissions* [11]. Either mineral planning authorities (MPAs), or on appeal the Secretary of State, will consider and may approve or refuse them according to their decision as to the acceptability of the proposals. In the case of an appeal, a public inquiry may be held and the inspector (Reporter in Scotland) may determine the appeal or make a recommendation to the Secretary of State. All planning permissions are subject to conditions controlling relevant aspects of the development, including noise and vibration.

5 Measures to reduce noise and vibration

5.1 Introduction

A typical mineral extraction operation will involve stripping of topsoil and removal of overburden, excavation and processing of the material to be extracted, transportation of material within the site and to markets and subsequent restoration of the land. The extraction of certain types of mineral can involve blasting.

All of these operations produce noise to some degree. Heavy vehicle movements carrying out these operations are a chief source of noise, whilst reversing warning signals are also a source of complaint (see **5.6.2**). The fixed plant used in extraction and processing of materials can also be a significant noise source, as can machinery used in site maintenance.

Subclauses **5.2** to **5.7** detail measures which can be employed to reduce noise and vibration. It is not intended that all of these measures be applied to every mineral extraction operation, but they should be employed as appropriate to individual sites.

NOTE. Further information on noise, ground vibration and air overpressure may be found in annexes A, B and C respectively.

5.2 Site planning

Prior to making an application for planning permission, an applicant should discuss with the mineral planning authority and, where appropriate, the relevant department of the local district authority, the predicted noise and vibration levels from the proposed site and any control measures to be implemented. This should highlight at an early stage any noise and vibration issues that need to be addressed. The application documentation should, where appropriate, contain information on the typical existing background noise levels and what the predicted noise and vibration levels would be as a result of the proposed development. Where a formal environmental assessment is undertaken, noise and vibration will normally be considered.

Site design and planning should aim as far as practicable to minimize any potential for adverse impact from noise and vibration on sensitive premises and recognize that working may take place in close proximity to such premises in order not to unnecessarily sterilize the mineral under excavation.

The location of activities within the site should where practicable take account of the potential impact of noise. Due consideration should be given to the topography of the area, natural screening effects and location of noise-sensitive premises. Care should be taken, where relevant, in the siting of such features as:

a) access points and parking;

b) limit of excavation;

c) yards and maintenance facilities;

d) screening, crushing and other plant;

e) internal haul roads;

f) stockpiling and loading areas;

g) pumps, generators and static plant;

h) overburden, topsoil and site bunds;

i) acoustic screens;

j) site amenities;

k) off site traffic routes.

The location of site activities clearly depends upon many factors related to the mineral, to the site and, in addition to noise and vibration, to other environmental considerations such as visual impact or dust. However, early consideration of such matters should enable the optimum site layout to be achieved.

5.3 Working methods

It is equally relevant to consider the methods of working to be adopted including the sequence and phasing of activities on site. Activities which are undertaken close to noise-sensitive properties may be programmed over a short period of time appropriate to local conditions. Often the order of site working can assist the minimization of any noise impact by locating plant within excavated areas and by using the working face as a screen when working towards noise-sensitive premises. This may not always be desirable or practicable with works such as soil stripping or bund creation. A common sense approach to such activities will help minimize the potential for any adverse environmental impacts.

The following factors should, where relevant, be considered:

a) order and phasing of site working;

b) depth and direction of working;

c) order and timing of particular operations;

d) location, gradient and screening of site roads;

e) location of plant and static equipment;

f) hours of working;

g) timing and frequency of blasting.

5.4 Working hours

The restriction of working hours for operations which may have an adverse impact on premises sensitive to noise or vibration may be considered as an alternative to the possible sterilization of the mineral resource. Such restrictions should only be considered where they are necessary. In certain cases extended operation is required for specific works (such as dewatering) and appropriate allowance should be made for this. It may in some circumstances be reasonable to limit particular operations or working phases to certain durations or times of the year, where this does not unduly conflict with the operation of the site. Alternatively it may be more appropriate, especially when dealing with established operations, to consider other practical measures for noise reduction as described above.

5.5 Site management

5.5.1 *General*

Good site practice depends upon suitably trained or experienced site operatives. Appropriate supervision and a commitment by all concerned to keep noise and vibration to a minimum can provide a cost effective way of achieving the objectives of this standard.

5.5.2 *Operatives*

Operatives should be familiar with the relevant conditions of the planning permission and other legislation and regulations, details of which should be available for inspection on site at all times. The site should be operated in accordance with these requirements at all times and where practical difficulties arise discussion should be sought with the relevant authority as soon as these become apparent.

Operatives should also be familiar with industry environmental codes and this standard which supplement the legislative requirements to assist effective site management. Site operations should be carried out in accordance with such guidance.

5.5.3 *Supervision and maintenance*

It is likely that noise and vibration will be important factors in any quarry plan and/or environmental management initiative, which may also involve monitoring of site performance or more detailed audits carried out by site staff or other appropriate parties. Records should be kept of any complaints received or other breaches of the controls or planning conditions relevant to noise and vibration as part of such initiatives and to assist effective site management. Liaison with local communities would support these site performance management initiatives.

Site supervision and maintenance are essential in ensuring that throughout its life, operations are carried out as they were intended. Plant and machinery (including measurement equipment) should be maintained in good working order and used in accordance with manufacturer's instructions. Special attention should be paid to any aspects which may affect the noise or vibration likely to arise, such as silencers or plant cladding and acoustic enclosures. It is also necessary to ensure that site baffle mounds, acoustic screens or other relevant site features are maintained such that they continue to be effective.

5.5.4 *Transport routing*

Measures should be in place to ensure that where it is intended that both on-site and off-site lorry traffic should follow a particular route, sufficient information is provided to all drivers and other relevant staff to ensure that they are aware of their responsibilities. This can be provided by on-site signage or through other information handed to drivers.

5.6 Practical measures to reduce noise

5.6.1 *General*

In general, the noise emission characteristics of any item of plant to be used should be established before it is used on site to enable the impact of its operation to be assessed. The aim should be, wherever practicable in any purchase of plant, to minimize the potential impact of noise.

NOTE. Periodic monitoring during operation may be desirable to confirm the noise characteristics of the item of plant and to check for any deterioration in acoustic performance.

5.6.2 *Noise reduction*

Noise sources likely to be encountered on site include trucks, loaders, dozers, excavators, sirens, screening and crushing plant, pumps, draglines, dumpers, drills and dredgers. Each site has its own particular characteristics and should be considered individually.

The movement of plant onto and around the site should have regard to the normal operating hours of the site and the location of any noise-sensitive premises as far as is reasonable.

The use of conventional audible reversing alarms has caused problems on some sites and alternatives are available. Audible reversing warning systems on mobile plant and vehicles should be of a type which, whilst ensuring that they give proper warning, have a minimum noise impact on persons outside sites. When reversing, mobile plant and vehicles should travel in a direction away from noise-sensitive premises whenever possible. Consideration should be given to the employment of other reversing warning systems to reduce the impact of noise outside sites, provided the chosen systems conform to applicable regulations, including those related to health and safety.

Careful positioning of noise barriers, such as bunds or noise screens, can bring about significant reductions in noise levels, although consideration should be given to the visual impact of such barriers. Planting of shrubs or trees can have a beneficial psychological effect but will do little to reduce noise levels unless the planting covers an extensive area. Barriers are most effective when positioned either close to the source or close to the receiver. The construction of a bund can be a noisy activity and may require careful planning, for example, it may be possible to construct the outer side of the bund first so that remaining work on the bund is shielded from noise-sensitive premises.

Examples of practical measures to reduce noise include the following:

a) avoid unnecessary revving of engines and switch off equipment when not required;

b) ensure plant and vehicles are properly maintained, check efficiency of silencers, lubricate bearings and keep cutting edges sharp;

c) if the noise source is directional, point the source away from noise-sensitive locations wherever possible;

d) keep internal haul routes well maintained and avoid steep gradients;

e) use enclosures for noisy plant such as pumps or generators;

f) use rubber linings in, for example, chutes and dumpers to reduce impact noise;

g) minimize drop height of materials;

h) limit the use of particularly noisy plant or vehicles;

i) start up plant and vehicles sequentially rather than all together;

j) ensure that plant and vehicles are operated with noise control hoods closed.

k) acoustic treatment, or retrofitting, of existing plant. Suppliers of plant will often have ready-made kits available and will often have experience of reducing noise from their plant.

5.7 Practical measures to reduce vibration and air overpressure from blasting

5.7.1 *General*

Most complaints of vibration relate to blasting. Blasting should only be used where there is no viable alternative. Good public relations have been shown to reassure the public of the fact that normal production blasting has not been found to damage property. In addition, contacting owners of sensitive properties to advise of imminent blasting can further help promote harmony with the public. It is good practice to publicize times when blasting will occur and to avoid blasting at other times whenever possible.

Air overpressure from blasting comprises transient airborne pressure waves which may be heard and felt. Air overpressure may be influenced by meteorological conditions over which operators have no control. Although air overpressure can be affected by the total quantity of explosives deployed in a blast, there is a balance to be struck between a smaller number of large blasts and a larger number of small blasts. Public relations have an important role to play in determining the optimum balance between size and frequency of blasting.

5.7.2 *Vibration and air overpressure reduction*

Practical measures, including good blast design, that have been found to reduce air overpressure and/or vibration are:

a) taking particular care with the development of faces and with trial blasts at a quarry as anomalous vibration levels may be produced when there is no free face to relieve the energy produced;

b) ensuring appropriate burden to avoid over or under confinement of the charge;

c) accurate setting out and drilling;

d) appropriate charging;

e) appropriate stemming;

f) using delay detonation to ensure smaller maximum instantaneous charges (MICs);

g) using decked charges and in-hole delays;

h) blast monitoring to enable adjustment of subsequent charges.

NOTE. Careful consideration may be necessary to avoid damage to cave systems and underground passageways.

Annexes

Annex A (informative)
Noise

A.1 Sources of noise

Noise can result from a large number of site activities on mineral extraction sites. The main sources of noise (excluding blasting, which is covered in annex C of this standard) arise from fixed and mobile plant. Specifically, power generation, screening, crushing and loading plant can produce high levels of noise. Potential issues may also arise from dump-trucks, scrapers, loaders, and dozers. Particular problems have been encountered with audible warning signal devices such as sirens and audible reversing alarms.

NOTE. Pumps, draglines, drills and dredgers may also need to be considered.

A.2 Criteria

Community and individual responses to noise from mineral extraction sites are dependant on a large number of factors. These include:

a) number of hours worked;

b) start and finish times;

c) days of working;

d) the overall duration of the working activity;

e) how established the works are, for example with regard to familiarization;

f) perception of detriment to amenity;

g) tonal or impulsive noise or noise with distinguishable characteristics;

h) the level of noise;

i) background and ambient levels of noise.

Because of the number of factors involved, it is not possible to limit noise to a single figure noise level which can be universally applied to all sites and all noise-sensitive premises.

NOTE 1. MPG 11 [7] and PAN 50 annex A [10] provide guidance on noise limits.

NOTE 2. Both rural and non-rural areas may be quiet areas or exceptionally quiet areas.

Definitions of daytime and night-time can depend on local circumstances. Guidance given in MPG 11 [7] suggests that daytime can be defined as being between 07.00 to 19.00, and night-time as 19.00 to 07.00. In addition to this the specification of an evening and dawn period (say 19.00 to 22.00 and 06.00 to 07.00) may be defined. The working week should generally be regarded as Monday to Friday and Saturday morning. Saturday afternoons, Sundays and Public/Bank holidays would normally be regarded as periods of rest.

NOTE. For long term fixed plant, BS 4142 may be used to assess the likelihood of complaint.

To allow specific work, for example soil stripping and baffle mound construction, to be carried out, higher noise level limits for short periods of time may need to be agreed. Guidance is given in par. 61 of MPG 11. It may be preferable for occupants of noise-sensitive premises to have a shorter, higher level of noise exposure than a longer term lower level noise exposure. The discussion and agreement of this with the MPA and local residents may be required.

Criteria may be set from one or more of the following:

a) individual items of plant;

b) at the site boundary;

c) at local noise-sensitive premises; and/or

d) at mutually agreed monitoring positions.

A correction factor (subtraction of 3 dB) is necessary to convert a measurement at a facade if the measurement is to be interpreted for the free field.

Further guidance on the establishment of limits is provided in BS 5228 : Part 1.

A.3 Monitoring

Monitoring of noise at sites where noise is an issue should be regarded as essential. Measurement may be carried out for a number of reasons, including the following:

a) to allow the performance of noise control measures to be assessed;

b) to ascertain noise from items of plant for planning purposes;

c) to provide confirmation that planning requirements have been complied with.

General noise monitoring from construction and open sites is covered in BS 5228 : Part 1 and specific monitoring of noise from surface mineral workings is detailed in MPG 11 [7] and PAN 50 annex A [10].

Monitoring positions should reflect the purpose for which monitoring is carried out.

Monitoring to ascertain if an item of plant or particular process is meeting an anticipated noise criterion or if noise control methods are working, may require measurements to be carried out close to the plant or process to avoid undue interference from other noise sources.

Monitoring to confirm that planning conditions imposed to protect local occupants have been met may be undertaken at noise-sensitive premises or at the site boundary, with a correction applied. The choice of noise measurement locations to be included in the planning conditions should reflect the requirement to accurately assess the noise.

Monitoring should be the responsibility of the site operator. Monitoring should be carried out by suitably trained personnel.

NOTE. Joint monitoring between the site operator and the local authority may be considered.

Annex B (informative) Ground vibration

B.1 Introduction

The primary cause of ground vibration on surface mineral extraction sites is blasting.

The level of vibration depends upon the distance from the blast, the maximum instantaneous charge weight of explosive, the delay sequencing and the geological nature and structure between the blast and receiver.

NOTE. Other processes such as block making may give rise locally to ground vibration.

Vibration can be measured in terms of acceleration, velocity and displacement. The relationship between these parameters depends upon the frequency of the vibration. Vibration peak particle velocity in millimetres per second is usually the preferred parameter for structural assessment. For human exposure BS 6472 (see **B.2**) requires the vibration time history, preferably in terms of acceleration, to be weighted and the vibration dose value (see **3.4**) compared with satisfactory magnitudes.

Vibration can disturb people in buildings and in extreme circumstances may approach levels capable of causing damage to buildings. The perception of vibration from blasting, however, can lead to fears of possible building damage. Air overpressure effects may be perceived shortly after ground vibration from the same event and reactions relate to both factors.

B.2 Criteria

BS 7385 : Part 1 gives information on the methodology for measurement, data analysis, reporting and building classification.

BS 7385 : Part 2 gives guidance on the assessment of the possibility of vibration-induced damage in buildings due to a variety of sources. This guidance indicates that the lowest value for the possibility of cosmetic damage from transient vibration is 15 mm/s.

BS 6472 provides guidance on human response to vibration. Tentative guidance is given on the magnitudes of vibration at which adverse comment may begin to arise. Annex C relates to blasting and advice is given on vibration measurement, factors which influence human response and satisfactory vibration magnitudes. A satisfactory magnitude of 8.5 mm/s for 90 % of all blasts is quoted in annex B with up to three blasts per day.

Annex A of Minerals Planning Guidance Note MPG 9 [11] and SOEnD Circular 26/1992 [12] give illustrative guides to the conditions. These state that:

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

This indicates that the statistical limit should be chosen, for example, between 6 mm/s and 10 mm/s and that the maximum value should not normally exceed 12 mm/s.

NOTE. BRE Digest 403 [13] discusses the issue and refers to the above standards.

B.3 Measurement of vibration

Vibration from blasting can be measured with seismograph equipment, with geophones or with accelerometers.

The peak particle velocity in millimetres per second can be measured in the three orthogonal axes at a point on the ground or inside a property.
Figure B.1 shows a two-storey building neighbouring a quarry with possible measurement locations indicated. The difference between vibration levels on the ground and inside a property can be illustrated as follows.

A blast occurs and vibration travels through the ground. At point A it can be measured as a ground vibration. At point B on the solid foundation of the house, the vibration level is lower than at point A, because of the loading on the foundations. At point C_1, on the ground floor, the vibration is the same as the foundation vibration for a solid floor, but it can be higher for a timber/joist floor. At point C_2 on a timber/joist upper floor the vibration is higher than the foundation vibration because of the lower mass and stiffness of the floor, allowing higher levels of vibration.

B.4 Prediction of vibration

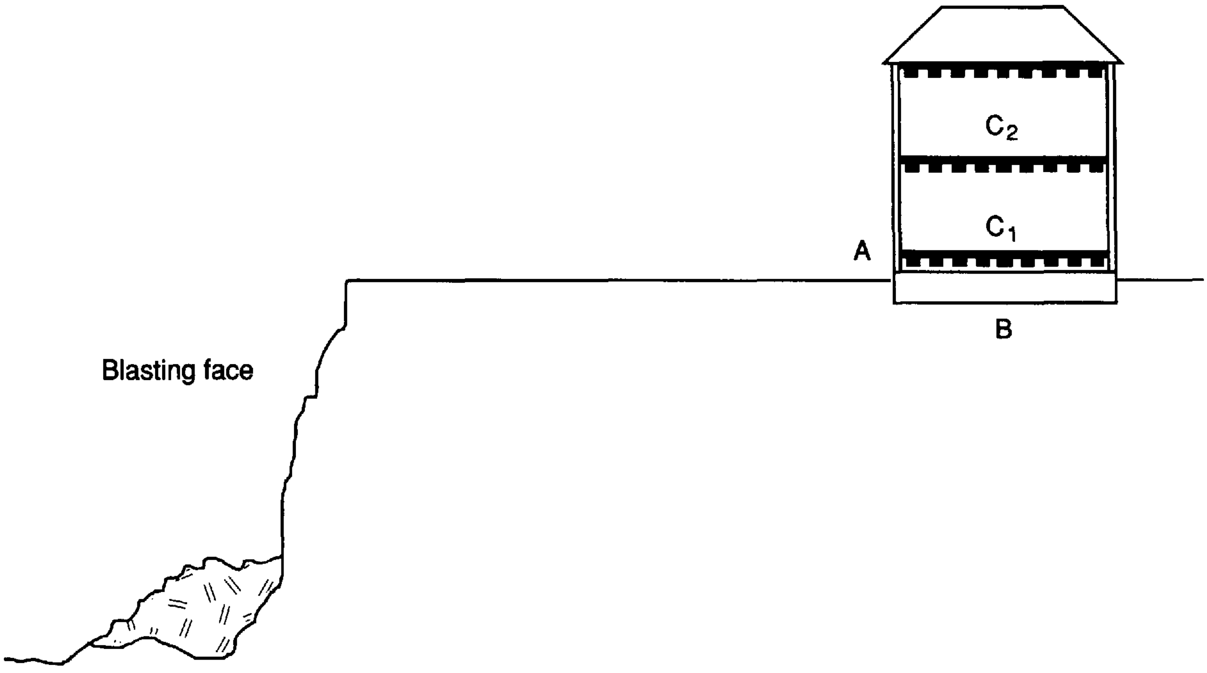
For any particular site, a number of measurements of vibration at different distances from the blast can be used to produce a scaled distance graph. An example of such a graph is shown in figure B.2. This plots the largest single component vibration against the distance m from the blast, divided by the square root of the maximum instantaneous charge. Vibration limits are commonly expressed as a statistical average to take account of the inherent variability of blasts. The scaled distance graph may be used as an indication of likely vibration magnitudes at various distances.

In order to calculate m for 95 % of blasts to be within 6 mm/s for a maximum instantaneous charge M of 100 kg, carry out the following procedure:

a) from figure B.2 read off the $\frac{m}{\sqrt{M}}$ value on the 95 % line at 6 mm/s. The answer = 20;

b) this means that $20 = \frac{\text{distance}}{\sqrt{100}}$;

c) therefore, distance = 200 m.



A = Outside on ground

B = Inside on foundation

C_1 = On timber joist or solid ground floor

C_2 = On timber joist first floor

Figure B.1 Sketch plan illustrating potential vibration measurement locations

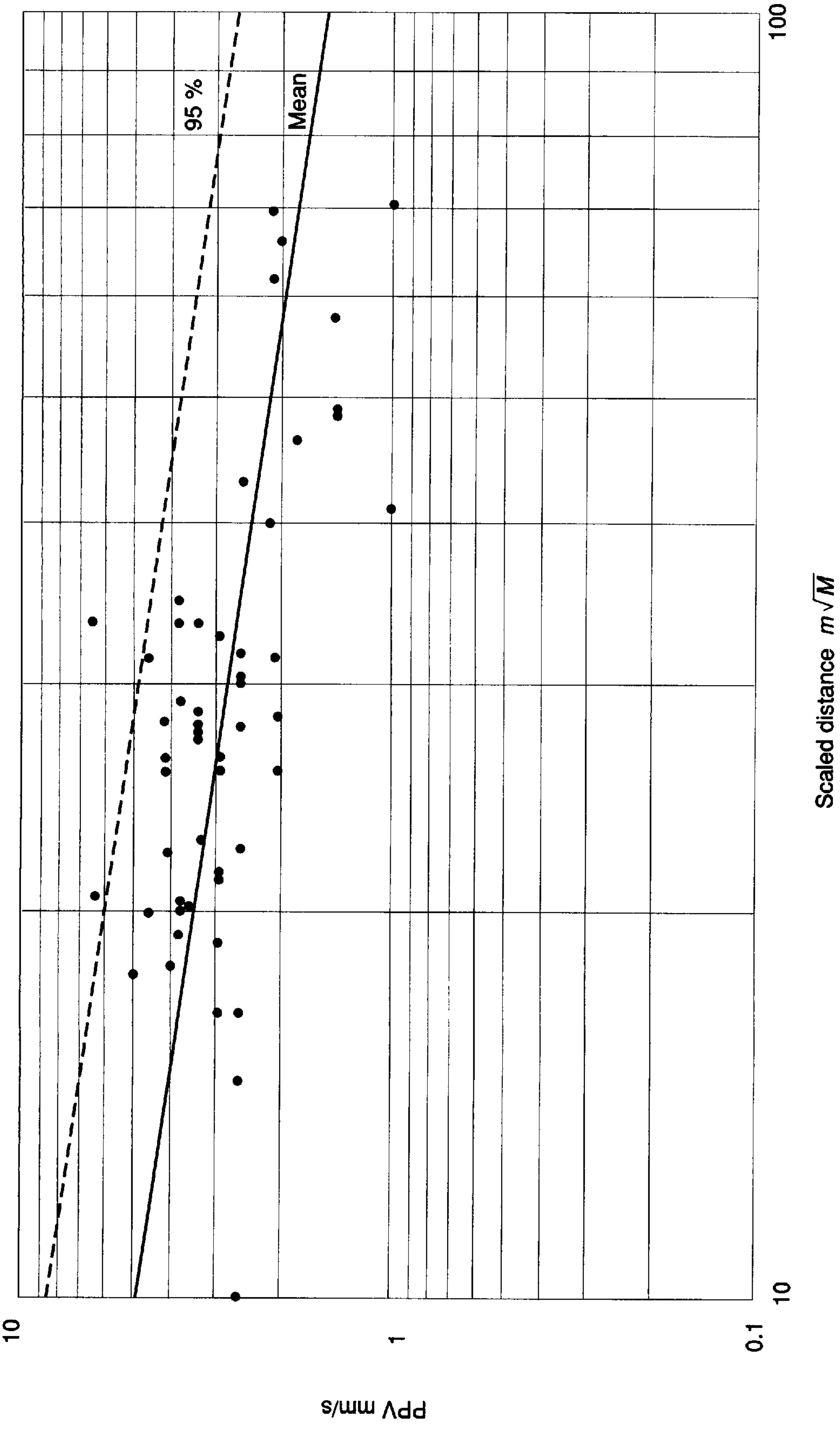


Figure B.2 Scaled distance graph

Annex C (informative)

Air overpressure

C.1 Description

Whenever blasting is carried out energy is transmitted from the blast site in the form of airborne pressure waves. These pressure waves comprise energy over a wide range of frequencies, some of which are higher than 20 Hz and therefore perceptible as sound, whereas the majority are below 20 Hz and hence inaudible, but can be sensed as concussion. It is the combination of the sound and concussion that is known as air overpressure.

The attenuation effects due to the topography, either natural or man made, between the blast and the receiver are much greater on the audible component of the pressure wave whereas the effects are relatively slight on the lower frequency concussive component. The energy transmitted in the audible part of the pressure wave is much smaller than that in the concussive part and therefore baffle mounds or other acoustic screening techniques do not significantly reduce the overall air overpressure intensity.

Air overpressure can excite secondary vibrations at an audible frequency in buildings and it is usually this effect which has been found to give rise to comment from occupants. There is no known evidence of structural damage to structures from excessive air overpressure levels from quarry blasting.

Meteorological conditions, over which an operator has no control, such as temperature, cloud cover, humidity, wind speed, turbulence and direction all affect the intensity of air overpressure at any location and cannot be reliably predicted. These conditions vary in time and position and therefore the reduction in air overpressure values as the distance from the blast increases may be greater in some directions than others.

C.2 Sources of blast generated air overpressure

The use of detonating cord, inadequate or poor stemming and gas venting are major sources of air overpressure and can be controlled with good blast design. The use of detonating cord can be avoided but, if used, any exposed lengths should be covered with as great a thickness of selected overburden as possible. Sufficient stemming with appropriate material such as sized stone chippings should be used. Gas venting can be minimized by good blast design, accurate drilling and careful placement of the correct amount of explosives. The other major sources of air overpressure from blasting are the reflection of stresses from a free face of an unbroken rock mass and also from the physical movement of a rock mass around the shot holes and at other free faces.

Detailed requirements for the use of explosives at quarries are contained in The Quarries (Explosives) Regulations 1988 [14].

C.3 Criteria

As the airborne pressure waves pass any single point the pressure of the air rises rapidly to a value above atmospheric pressure, falls to below atmospheric pressure, then returns to normal pressure after a series of oscillations. The maximum value above atmospheric pressure is known as peak air overpressure and is measured in pressure terms and generally expressed in linear decibels (dB lin) (See **C.4**).

Routine blasting can regularly generate air overpressure levels at adjacent premises of around 120 dB (lin). This level corresponds to an excess air pressure which is equivalent to that of a steady wind velocity of 5 ms^{-1} (Beaufort force 3, gentle breeze) and is likely to be above the threshold of perception.

Windows are generally the weakest parts of a structure and research by the United States Bureau of Mines [15] has shown that a poorly mounted window that is prestressed may crack at 150 dB (lin), with most windows cracking at around 170 dB (lin), whereas structural damage would not be expected at levels below 180 dB (lin).

C.4 Measurement

Measurement of air overpressure needs to be undertaken with microphones with an adequate low frequency response to fully capture the dominant low frequency component. A 2 Hz high pass system has been found to be satisfactory. Most of the equipment more commonly used for noise measurement is therefore not suitable for measuring overpressure.

Although monitoring of air overpressure can be undertaken, due to the uncertainties with meteorological conditions, it is not possible to predict the location of the maximum air overpressure. Additionally, pressure variations in the atmosphere due to windy conditions can mask the blast generated air overpressure levels. For these reasons it is not accepted practice to set specific limits for air overpressure. In order to control air overpressure the best practical approach is to take measures to minimize its generation at source.

Annex D (informative)

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