Structural response to vibration

A buildings response to vibration is complex and can be attributed to varying factors within the property and the underlying geology. The age, construction type, shape and size of a property also varies the response from a blast and thus the felt human perception.

If the frequency from ground vibration matches the natural frequency of the structure (or part of the structure), a high response can be expected, which can vary across the property. The table below is from a manor house built and rebuilt in the 16th and 19th centuries.

Location	Resultant (mm/s-1)
At footings of property	0.64
Kitchen	0.51
Ground Floor Lounge	1.14
1st Floor Landing	1.66
2nd Floor Landing	1.11
2nd Floor Bedroom 1	1.38

An example property (values vary across varying property types)

All resultant vibration values recorded from within the property are equal to or just about the threshold of the human perception to vibration (0.5 mm/s-1) and are considered to be low but perceptible. It is important to note how the vibration level varies over the additional property floor levels.

Structural response to air overpressure

Air overpressure (measured in dBL - linear decibels) is often the most perceptible result of blasting at larger distances.

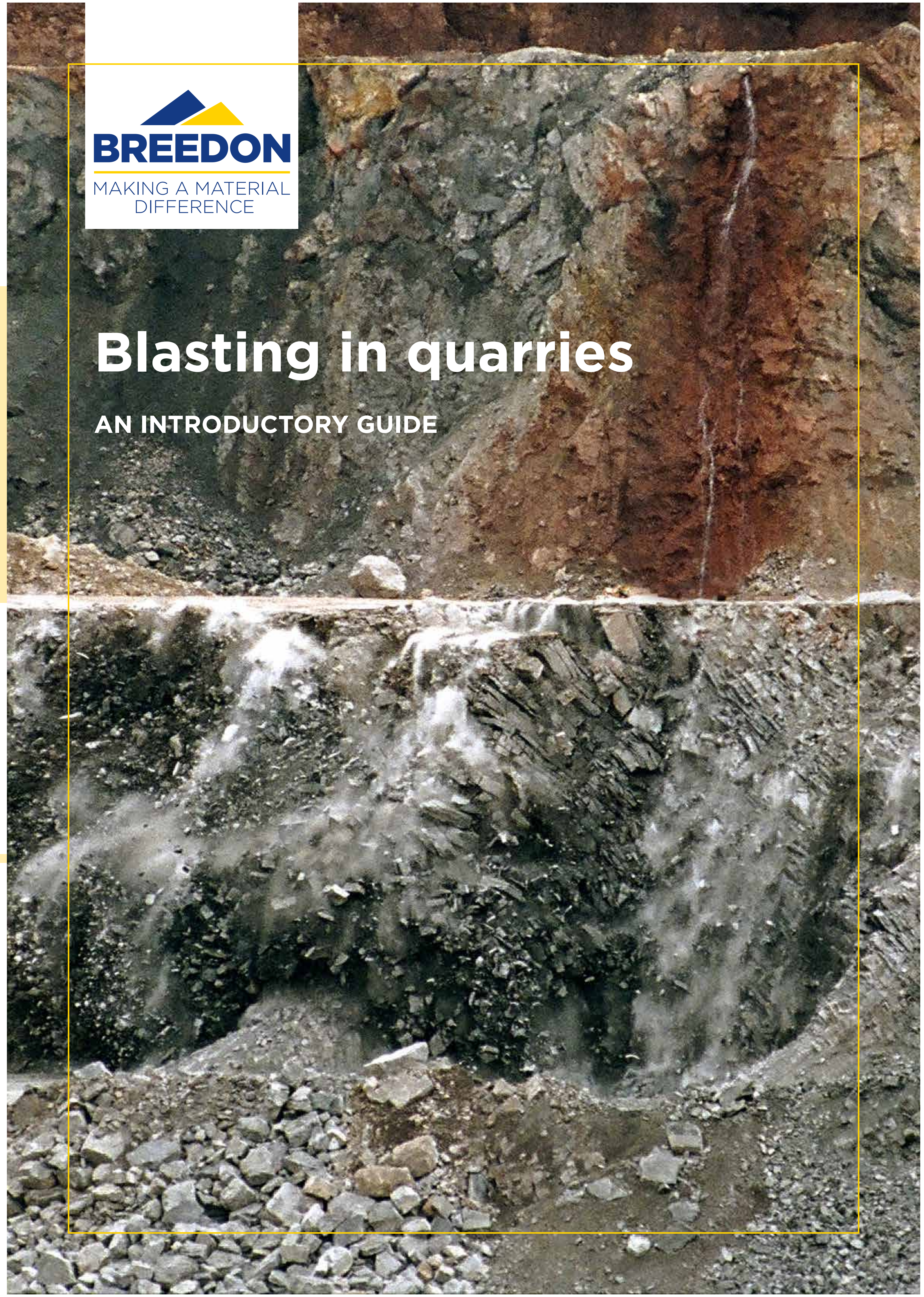
Ground vibration arrives at a receptor first followed by the impact of air overpressure. The air overpressure is often perceived as a greater effect due to the receptor being alert and ready after the first movement. The time lag between the two events is dependent on the distance from the blast, the speed of vibration through the rock and the speed of sound through air on the day of the blast.

Damage criteria	Air overpressure (dBL)
Structural damage	180
General window breakage	171
Occasional window breakage	151
Damage threshold	140
No damage	**134**

Although air overpressure below 140dBL will not cause structural damage, pressure levels at around 120dBL can rattle windows and loose items in the building such as doors, etc.

EXAMPLE

www.breedongroup.com



BREEDON

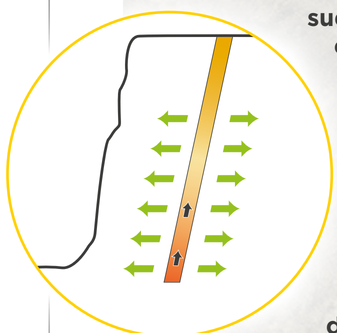
MAKING A MATERIAL DIFFERENCE

Blasting in quarries

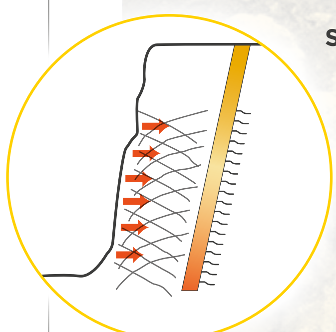
AN INTRODUCTORY GUIDE

Breedon is a leading construction materials group in Great Britain and Ireland. We produce cement, aggregates, asphalt, ready-mixed concrete, Welsh slate and specialist concrete and clay products, and offer a range of contracting services.

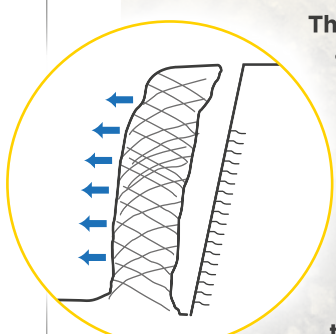
Rock Breakage



When an explosive charge is detonated there is a sudden release of stored energy in the form of an explosion of gas at high temperature and pressure. This sudden release of energy produces a compressive pulse which fractures the overall mass of rock with the energy decaying as it travels out through the rock mass.



Since rock has a high compressive strength, the energy passes through the surrounding rock until it reaches a free face (an open quarry face) where the energy is then reflected back producing tensile waves.



These tensile waves tear apart the now fractured rock and breaks it up into smaller loose pieces. The uplifting and churning nature of the expanding gases (thrust energy) further disintegrate the rock and cause the material to settle in a blast pile.

What is blasting?

Blasting is an essential part of any quarrying operation. The technique utilises energy from detonated explosives to break and loosen rock to a suitable size, which can be excavated and processed for use in the construction industry.

The method is used throughout the world and has been the technique of choice for hundreds of years. Today, the controls and regulation are much tighter and technology behind the blast have significantly changed improving the operational performance whilst reducing the impacts.

Whilst vast operational improvements have been made, not all of the energy produced when the explosive is detonated goes into breaking the rock. Some wasted energy is dissipated in the form of noise, heat and gas with the two most noticeable being:

- **Ground vibration** – caused by seismic waves travelling through the ground
- **Air overpressure** – caused by pressure waves travelling through the air (soundwaves)

However, with careful design and execution, the wasted energy can be minimised reducing the effects of vibration and sound.

Blast Design

A computer model is created showing the extent and size of an area to be blasted to ensure sufficient volume of rock is broken. A design for the blast is then created and used in the preparation.

Several holes are drilled in rows vertically into the solid rock mass and an explosive charge is placed within the hole. The explosive charges are linked together with a small delay applied to each detonator. This results in several explosions over a very small period of time. This is done for various reasons, including reducing the overall instantaneous explosion, thus reducing the blast effects. It also has a better result on the final broken rock size.

Data from every blast, including photographs, videos and logged vibration and air overpressure are noted and recorded for auditing and reviewing processes.

Impact on the environment

The energy released during the explosion results in ground vibrations which are transmitted by adjacent particles being moved and air overpressure (soundwaves).

Ground Vibration

The amount of movement is directly linked to the amount of explosive used and the distance from the explosion and thus the effect on any person or structure will depend on how much these particles move wherever they are present.

Vibration can be monitored using a vibrograph which measures units of movement:

- **Displacement (mm)**
- **Velocity (mm/s)**
- **Acceleration (mm/s²)**

Velocity is almost always used to measure ground vibration, due to the cost of data collection, the ease of use, the repetitive nature and the correlation with damage.

Air Overpressure

The sound and air pulse generated from the explosion is often heard for some distance from the blast. Cold, damp and windy days can increase the perception of a blast as the soundwave is able to travel further.

The sudden movement of air can also result in other factors such as rattling windows and doors as the air moves over them.

The most important function of the air pressure wave is its frequency – the number of vibration cycles a second measured in Hertz (Hz).

Impact on humans

The national planning framework across the UK puts a limit of the permitted amount of vibration at any site at 12mm/s.

The table below shows the effects of the level of vibration.

Vibration levels

Peak Particle Velocity (PPV)	Effect
>50 mm/s	Minor structural damage
14.3 mm/s	Extension to existing crack in plaster
17 mm/s	Door slamming
3 mm/s	Foot stamping
0.5 mm/s	Human perception

At a site where blasting is permitted, a local maximum vibration level will also be set. This level of vibration is determined on various local factors, including the proximity of human receptors however is always lower than the national limit of 12mm/s. This limit will be set within the planning permission for the site and if breached, the site will be operating illegally.

The human body is very sensitive to vibration and the majority of people will generally become aware of blast-induced vibration at levels around 1.5mm/s, but some will feel it at levels as low as 0.55mm/s.

Whilst they can be felt, and often heard, these vibration levels are around 1/100th of the level necessary to damage structures and are also far lower than those produced by many daily activities like walking, door closing and washing-machine cycles.