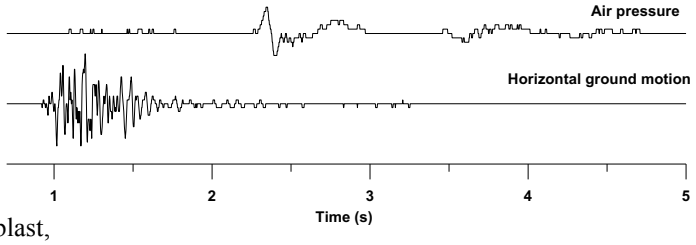
ARIZONA MONITORING SERVICES

Phoenix, Arizona

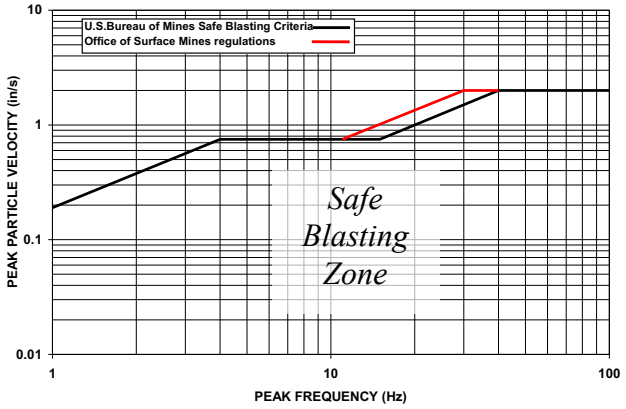
ROCK BLASTING, GROUND VIBRATIONS, AND AIRBLAST

WHAT ARE BLASTING VIBRATIONS AND AIRBLAST?



Ground vibrations and airblast are measured as time-histories (shown to the right) with amplitude and frequency (number of oscillations per second). The amplitude of ground vibration, measured as velocity (in/sec), attenuates or decays with distance while the frequency decreases. Airblast is the airborne pressure, measure in lb/in^2, occurring from rapid ground surface movement and, in some cases, when explosive gas products escape during detonation. It is ground vibrations, and not airblast, that correlate with structure damage but *only at very high* ground velocity levels, well above levels that you will experience. Airblast does not cause damage to structures at the levels generated from rock blasting but may startle persons inside structures.

WHAT ARE THE SAFE STANDARDS FOR BLASTING?



Safe blasting standards were proposed by the U.S. Bureau of Mines, (USBM) and shown to the right, based on over 40 years of studies that included direct crack observations correlated with ground vibrations. The Office of Surface Mining adopted the USBM criteria as regulation (with modification shown) applied only to coal mine blasting. Frequency-based standards (shown to the right) limit maximum ground velocity as a function of frequency at the peak velocity. Blasting below this line is safe as this line represents the 100-percentile (or level of assurance) that threshold cracking in wall materials, such a drywall, *will not occur*. Above this line, damage may occur at increasing intensities as peak velocity increases. These are the standards to which our project blasting will adhere.

As damage is probabilistic, the USBM provided a range to *the lower limits* of peak ground motions at which three categories of damage may appear as ground velocity at the structure increases:

Threshold or cosmetic	0.75 – 2 in/sec	such as new hairline cracking or crack extensions in interior drywall or exterior stucco
Minor damage	2 – 5 in/sec	cracking in masonry such a bricks or mortar, separations between construction components
Major damage	8 – 10 in/sec	concrete slab cracks, windows and doors out of alignment

These standards have been adopted as law by some state, county, and city regulatory bodies for quarry and construction blasting. In the absence of regulations, this criterion is widely employed by blasters when blasting is conducted near structures and now serves as the industry standard for safe blasting in the U.S. for all types of structures and blasting in all types of geology. *To this day, there has been no scientific study that challenges these standards.*

HOW DO STRUCTURES RESPOND TO BLASTING?

Ground vibrations and airblast are felt by persons inside structures even at very low levels of amplitude of 0.01 in/sec, far below levels that could possibly cause cracking. Excitations from blasting contain many different frequencies that may readily transfer into a structure, causing structure components to shake. When the predominant frequencies are close to the structure natural frequency (4-12 Hz for whole structures and 18-25 Hz for mid-walls), the structure may respond from motions in the ground and air, depending on the amplitudes. The inside "noise" you may perceive is associated with higher frequencies that may generate mid-wall motions, leading to rattling of loose objects resting on or against walls. These structure motions are very low in amplitude and are not harmful in any way but may startle and alarm you and leave you with the impression that damage may be occurring. However, no damages from blasting will occur at the levels we will be blasting, guided by the safe blasting criteria.

WHAT PEOPLE FEEL

Air pressure travels slower than vibrations in the ground (shown by the time histories above). If you are inside your house, you may first sense vibrations beneath you feet, followed by wall and upper structure motion "noise" (described above). Certain structures may readily respond to the low frequency energy of airblast (lightly loaded structures, large exterior walls or highly peak roofs). As such, the duration of structure shaking may be longer than the duration of the ground motions alone. Farther from the blast, you may feel what you perceive as two blasts when indeed the structure may respond separately to the ground, then the air pressure.

HOW DOES THE BLASTING COMPANY PROTECT NEAR-BY STRUCTURES?

Blasters are trained, experienced experts in their field. They must comply with many strict safety and security regulations that cover transportation, storage, and handling of explosives. Blasters also understand off-site impacts of blasting and know how to design each blast to minimize airblast and ground vibrations, keeping levels as low as practically possible while performing their job. Blasters know how to load each blasthole to minimize the explosive charge weights, to place the correct amount of crushed rock "stemming" material at the top of each blasthole to prevent airblast, and to correctly time each blasthole detonation with millisecond (ms) delays.

The blaster has your safety and the protection of your home in mind at all times. The developer is concerned about your comfort level and will provide open lines of communication within your neighborhood during the construction process.

THE USE OF BLASTING SEISMOGRAPHS

Blasting seismographs are usually placed at the closest structures surrounding the blast site as a control measure to ensure that the amplitudes of airblast and ground vibrations are as expected and well within safe standards. They are used for quality control and to protect your property. Blasting and seismic reports are reviewed after each blast and the information often used to re-design the next blast if necessary. Blasting and seismograph records are always retained by the blaster for future reference in the event questions arise about the blasting. The use of blasting seismographs, the printing of full waveform time-histories, and careful attention to predominant frequencies are very important in understanding the off-site effects of each blast.

OTHER ISSUES

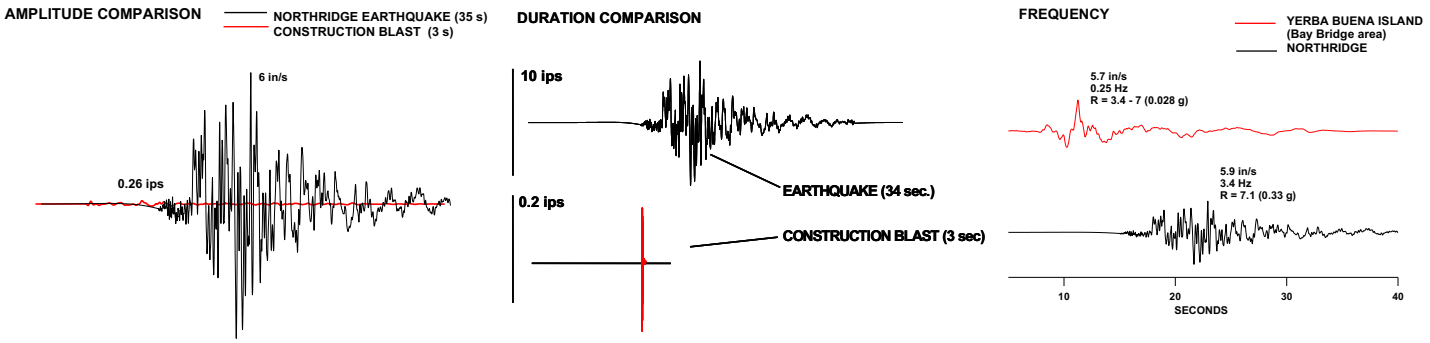
When blasting takes place near communities, questions and concerns often arise by community members that go beyond the issues addressed above. *These concerns are normal* as they often stem from the fear that damage to structures is taking place at *any* level of vibration perceived by persons inside their homes, even at ground motion levels that are scientifically proven to be far below the threshold of minute hairline cracking. Some of these issues and concerns are discussed below.

REPEATED EFFECTS

Many home owners accept that ground motions measured outside their home below the safe blasting criteria will not cause cracking today. But what about the future? Do the effects of repeated blasting every day accumulate in structures such that defects will start showing up long after the blasting is done? This question was addressed by the USBM in a 2-year blasting study near one home and by many other researchers since that time. Repeated effects were carefully researched. The USBM study found that as long as blasting takes place within the safe criteria, wall strains are far below the "elastic" or recoverable limit and do not accumulate or add over time. There has never been any validity to concerns of repeated effects and numerous researchers continue to study this topic.

EARTHQUAKES

Many community members may have experienced an earthquake in the past. We know that earthquakes may be very damaging to structures. Blasting vibrations are often compared with earthquakes. Even though blasts and earthquakes may *seem* similar, they are very different for a number of reasons. Blasting generates ground motions that are much lower in amplitude, far shorter in duration and higher in frequency than earthquakes. As such, careful blasting does not cause structure damages whereas earthquakes often do.
The following figures contrast the difference between earthquakes and blasting:



(a) (b) (c)

Figure (a) compares the amplitudes for a typical construction blast (0.26 in/s) in red and an earthquake (6 in/sec) in black
Figure (b) compares the duration of a blast (3 sec) with the duration of an earthquake (34 sec)
Figure (c) shows the frequencies of two earthquakes (above) 3.4 – 7 on the Richter scale generating 0.25 Hz frequency at the peak and (below) 7.1 on the Richter scale generating 3.4 Hz.

HOW DOES BLASTING RELATE TO THE RICHTER SCALE?

The Richter magnitude scale was developed in 1935 as a mathematical device to compare the size of earthquakes from a number of monitoring locations to establish the epicenter (origin) of a quake. On the Richter scale, magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Except in special circumstances, earthquakes below magnitude 2.5 are not generally felt by humans.

There is no direct comparison of the energy of vibrations from blasting with the Richter scale (R). The Richter scale is not used to express damage to structures as it does not represent intensity but rather magnitude. Therefore it is not appropriate to compare Richter magnitude numbers to blasting intensity if cracking potential is being considered.

I KNOW THAT CRACKS HAVE FORMED SINCE THE BLASTING

When blasting is heard and felt, it is human nature to start looking for cracking around the house. Many homeowners subsequently will find a number of cracks, noted for the first time, and associate them with the blasting activities. Indeed these cracks were present before blasting began and simply not noticed before! We specifically design the blasts such that *no cracking* will occur in structures. As such, it is important for you to become acquainted with the existing conditions of your home. Therefore, we would encourage you to take a visual inventory of the cracks in your home prior to the beginning of blasting.

IF BLASTING IS NOT CRACKING MY HOME, WHAT IS?

Cracking in structures is *normal and expected* over time. Cracks readily form in new construction for many reasons based on subtle, differential soil deflections and natural aging of new construction materials. Soil deflections up to 0.5 in are normal. Anything greater then this may be a sign of foundation problems. Shrinkage of construction materials such as new concrete, mortar, and wood framing is the largest contributor to cracking in residential structures. “Green” wall studs may shrink 2% to 11% in width upon drying after construction depending on the wood grain orientation with the wall. Post-construction natural atmospheric humidity fluctuations will create differential expansion and contraction of wood members, resulting in potential wall and joint stresses, separation and cracking, and the common “nail popping” as nail heads naturally deflect outward from the wall. Thermal stresses from daily temperature fluctuation also cause material expansion and contraction of stucco and drywall that may result in hairline crack formation.

Older construction may crack for the first time from changes in structure loading or foundation soils conditions as well as every-day human activities. With aging, water pipe joints may leak and saturate the soils beneath your structure, causing compaction, consolidation, or even expansion of the soils and may result in cracking of concrete slabs and tile flooring. Storms with high winds may load structure walls, causing cracks to expand and lengthen. Residents running through houses, slamming doors and windows, dropping heavy object in a room, and even running a garbage disposal can create wall and structure vibrations that are often as great as or greater than those caused by blasting!

There are hundreds of reasons why cracks appear in construction materials with age, wear and tear, and use of a home. The most common environmental and human factors that lead to cracking in drywall, stucco, masonry, wood, and other materials include the following:

- short-term and long-term changes in temperature and humidity (leading to large expansion/contraction material strains)
- water intrusion through cracks and around foundations from broken water pipes or leaking hose bibs
- transient wind and earthquake loads
- soil conditions at time of construction or changes in soils after construction (soft, wet clays, improperly compacted or poorly drained fill, expansive clays)
- improper foundation design for the range of anticipated soil conditions
- unsupported upper structure spans
- inferior or “green” construction materials
- normal, everyday household activities

All of these forces create strains in construction materials that often exceed those generated in structures from blasting within established safe limits and are often greater than the failure strain of the weaker material (such as drywall and stucco). Remember that minor cracking in construction materials is normal and is expected. Extensive cracking may be a sign of structural problems and an expert should be immediately consulted.

CALL IF YOU HAVE CONCERNS

During the blasting process, representatives are available to speak with you about your concerns. If you have questions or concerns, you should contact the representatives listed on the letter you received. If you did not receive a letter, please contact the developer for the project.