Can Blasting Trigger an Earthquake?

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This is a reasonable question, usually asked by someone who has a very real concern that it could happen. To arrive at the answer, however, requires some research and investigation into the mechanisms involved in earthquakes.

In 1994 I was asked to analyze the potential hazards and risks of blasting for Milagra Terrace, a proposed housing development near Pacifica, south of San Francisco. The total amount of rock to be removed was rather small, on the order of only two to three thousand cubic yards. There would also be some minor blasting to install utilities. Assuming reasonable blast designs, there would have been no adverse impacts on neighboring homes. One of the project opponents' concerns, however, was that the blasting would take place in close proximity to the San Andreas Fault, the surface trace of which was located a short distance east of the development. Several opponents argued that blasting would surely trigger an earthquake. The project owner, the Planning Department and several members of the City Council wished for me to address this concern.

In order to answer such a question, the first thing to consider is the actual location of the source of an earthquake. While a fault trace may be visible on the earth's surface for some earthquake faults, the actual focal point or source of an earthquake is located deep in the earth where the rock near the base of the fault has been locked in place. Strain is constantly building at this point and, when the strain becomes too great, the rock fails and the earth shifts. The point where the rock fails and the energy is suddenly released is called the hypocenter (or focal point) of the earthquake. If such a locking point did not exist, the strain would not build to such an extent because one side of the earthquake fault would slowly creep past the other. The epicenter that you hear about in news reports is a point on the surface of the earth directly above the hypocenter. Earthquake hypocenters are normally located from 15 or 25 to 60 kilometers below the earth's surface, although a few small ones have been calculated to be at a depth as shallow as 6 kilometers (see Richter, 1958). The initiating point of the energy release from an earthquake is located at these depths and this is where it would have to be triggered. The surface fault trace that you can see (or that may be hidden below the earth's surface) is actually an extension of the fault and is an effect of the earthquake rather than the cause of it.

So the question becomes how much of a triggering force might be felt at the hypocenter from blasting at or near the earth's surface? Obviously we can impart a fairly large impact (depending upon the size of the blast) on portions of the surface trace of a fault and, in fact, this occurs on a regular basis.

(See references at the end of this article.)

Blasts near earthquake faults occur regularly near Permanente, Corona, Davenport and other locations in California. In several instances, tunnels have been driven through earthquake faults by blasting. No earthquake has been known to have been triggered by blasting in close proximity to an earthquake fault.

We can readily estimate the maximum vibration that would be generated by any given weight of explosive at a particular distance. The formula for doing so is:

$$\mathbf{PPV = H \times (Dist / Wt^{0.5})^{-1.6}} \qquad \text{where}$$

PPV is the vibration intensity expressed as Peak Particle Velocity in in/sec,

H is a factor that can vary between approximately 24 and 242, depending upon site factors.

Dist is the distance in feet between the detonating charge and the location of interest.

Wt is the maximum weight of explosive (in lbs) detonated within any 8 ms time frame.

The attenuation slope of **-1.6** is typical for most blast-generated vibration.

(Some may recognize that $\mathbf{Dist / Wt^{0.5}}$ is often referred to as Square Root Scaled Distance, a blast scaling tool that has no units.)

For estimating the blast vibration, we have to select a representative charge weight of explosives. Blasts at construction sites and at open pit mining locations usually subdivide the total amount of explosives in a blast into smaller quantities that are detonated on individual delays. These delays are separated by 9 to 25 milliseconds or so. This is done to, (1) control vibration at nearby structures, (2) improve fragmentation and, (3) control the distance and direction of the heave of the blasted rock. Except for certain specialized blasts, it is usually not practical nor is it advisable to detonate large blasts without subdividing the explosive weight into such delays. Vibration intensity is proportional to the square root of the maximum charge weight per delay rather than to the total explosive weight in the blast.

Let's use as an example a charge weight of 10,000 lbs per delay as being a reasonable largest practical charge weight per delay for conventional blasting. Although it could conceivably be larger, more often it would be smaller. We can also use the previously mentioned 6 kilometers (19,684 feet) and 15 kilometers (49,212 feet) for our example distances.

We will have to select a value for the factor **H** in this hypothetical exercise. An average value of 160 for estimating vibration along a horizontal surface would be appropriate; however blast vibration intensities at depth have been estimated to be from 1/3 to 1/2 of those on the surface (Oriard, 2002). Body waves, both compression and shear, dissipate more rapidly than do surface waves. At fairly large horizontal distances, surface waves dominate. There are no surface waves at depth. Also, because velocities within the earth increase with depth, the body waves will tend to curve back toward the earth's surface, further reducing the impact at depth. Although it is probably smaller for body waves at depth, it would be reasonable to use half of 160, or 80, as the factor **H** for our calculations.

Using 80 for the factor **H**, a charge weight of 10,000 lbs and using distances of 6 and 15 km respectively, we estimate that Peak Particle Velocities would be as follows:

$$80 \times (19{,}684 / 10{,}000^{0.5})^{-1.6} = 0.017 \text{ in/sec (at a depth of 6 km)},$$

and

$$80 \times (49{,}212 / 10{,}000^{0.5})^{-1.6} = 0.004 \text{ in/sec (at a depth of 15 km)}$$

Blast vibration intensity with peak particle velocities of 0.004 or 0.017 inches per second would not be capable of doing cosmetic damage to sensitive structures, let alone being able to trigger an earthquake.

It should be noted that in these estimations we have used rather large charge weights and a factor for **H** that is probably too high considering the reductions in vibration previously recorded at depth. In spite of using overly aggressive criteria the vibrations are still quite low, mainly due to the large distances involved. If one were to further increase the charge weight and use an even higher **H** factor, the resulting vibration estimates would still not reach levels where they could adversely impact the locked portion of the earthquake fault at depth.

To further reinforce the argument that blasting could not trigger an earthquake, two good examples of extremely large blasts in the vicinity of earthquake faults should be considered. These blasts were the two coyote blasts that were detonated to obtain rock for the Ord River Project in Australia (see Oriard, 2002). Unlike conventional blasts, coyote blasts detonate a large quantity of explosives nearly instantaneously inside tunnels in order to fracture a large volume of rock. Usually the rock has jointing systems that will allow it to fracture adequately when the rock mass is lifted by the force of the explosion and then dropped. The two coyote blasts at Ord River detonated 994,000 lbs and 1,154,000 lbs respectively. There were two faults in very close proximity to the blasts. The Blind Gully fault and a connecting fault were immediately adjacent on opposite sides of the rock ridge where the blasts were located. The site was instrumented and, following each of the blasts, a survey was done to determine if there had been any movement along the faults. None was found.

Some might wish to make the case that even minor vibration levels from a blast could be enough to trigger an earthquake when the strain at the focal point is at a peak and an earthquake were just about to occur. In other words, vibration from the blast would be the straw that broke the camel's back. This could not be the case, however, because the strain would have been elevated well above that of the blast vibration numerous times previously by other stronger sources (such as other nearby earthquakes on the same or other faults, the moon's gravitational pull, tidal effects, etc.). These sources would have had a greater impact on the locked focal point than the small impact from a distant blast on or near the surface.

It is unfortunate that man cannot trigger an earthquake by blasting in close proximity to a fault. If it were possible to do so, we might intentionally trigger small earthquakes in fault zones that were locked. Instead of experiencing large earthquakes with a magnitude of 6 to 8 or higher on the Richter scale when the rock fails, it might be possible to regularly nudge the locked point into slipping with a resulting earthquake in the range of 2 to 3 or smaller.

Portions of the San Andreas Fault System (SAFS) manage to creep along at an average rate of a little less than 1-1/2" per year (about as fast as your fingernails grow), while other portions that have been locked for long periods of time will only shift when the rock's strength is exceeded by the strains that have built up, resulting in a major earthquake. The zones that creep or shift with small earthquakes may cause some inconvenience, but preventing major earthquakes that result from locked portions of the SAFS would be a huge benefit if we were able to do so.

Several technical advances would have to be made in order for such a scheme to work. Drilling accurately to a depth of 15 kilometers or more could be difficult. Accurately locating potential hypocenters would be necessary. Nuclear devices would probably have to be used in order to provide sufficient energy in a small package. A chemical explosive charge of sufficient size would require too much volume. The proposed use of nuclear energy for such a purpose would surely be opposed by some for environmental and/or political reasons. Elevated temperatures at depth could be a possible problem. The process would have to be initiated at some location on the fault shortly after a major earthquake had just occurred, otherwise the strain would build up again and any subsequent man-made earthquake could reach major proportions. Implementing such a scheme would also be problematic in today's litigious society. Even if the nudging of a partially locked fault were successful and resulted in a relatively minor earthquake, it is possible that there would be claims of perceived damage.

Mother Nature will continue to relieve the strain that develops from plate tectonics in her own way and in her own time frame and we currently have to accept the consequences. Blasting, however, has not been and will not be a contributing factor in triggering earthquakes.

References:

Oriard, L. L. (2002), *Explosives Engineering, Construction Vibrations and Geotechnology*, published by the International Society of Explosives Engineers.

Richter, C. F. (1958), *Elementary Seismology,* published by W. H. Freeman and Company, Inc.

Recommended further reading:

Shearer, Peter M. (2009), *Introduction to Seismology, 2nd Edition,* published by Cambridge University Press.

Bullen, K. E. (1963), *An Introduction to the Theory of SEISMOLOGY, Third Edition*, published by the Cambridge University Press.