Seismic Anomalies, Errors and Just Plain Mistakes

Author: Wes Bender

Let's assume for the moment that you are carefully recording the vibration from your blasts and that you are further plotting the data on a logarithmic chart so that you have a site-specific prediction curve, from which you can develop future blast designs and predict the resulting vibration. Do you occasionally have readings that don't plot well with the previous data? Have you investigated to determine why? Did you flag the suspect data so that consideration can be given to it if someone else analyzes the data later?

It might prove beneficial to look at some of the ways that erroneous methods, data, reporting or analysis can skew the results.

At Box Canyon Dam in Northern California, analysis of the seismic records allowed us to determine the cause of a rather high vibration reading. We had recorded a little over 4 in/sec of peak particle velocity. We were limited to (and expected to record approximately) 2 in/sec at the recording location. Analysis of the seismograph tapes showed that several holes that were supposed to fire later in the initiation sequence detonated sympathetically with the fourth hole, resulting in a reading that was slightly over 4 in/sec. The tape allowed us to show the owner's engineer where the problem was and blasting was allowed to continue using less sensitive explosives. Where do you make the correction to the records? The vibration readings were accurate, but the Scaled Distance number in the records had to be corrected to show the increased charge weight for the fourth delay. A note was placed with the records explaining the situation.

In another instance, vibration data from tunnel blasting was being collected by an engineering firm. Among other tasks, I had rented the equipment to them and assisted in the installation. The data was not only being used to verify compliance with vibration limits, but also to provide prediction capabilities for future blasts closer to the protected object. The firm was using Lew Oriard's prediction curves and was plotting the data against Lew's curves for upper and lower bounds for normal confinement. They were concerned because the plotted readings were consistently 25% to 30% higher than what they anticipated. In going over the vibration data with them, it was discovered that they were plotting peak vector sum on the graph rather than individual channel peaks. They thought they were doing it correctly. I had them go back and plot individual channels rather than vector sum and the data promptly fell within the bounds as expected. I did explain that, yes, true vector sum is really the actual highest vibration, but that all of the standards on which our limits are based used individual channel peaks (as do Lew's curves too). In this instance the data recorded was correct, but the analysis method was not. (Vector sum can often be from 10% to 35% higher than individual channels. If vector sum were to be used as a limit, it should be adjusted upward accordingly.)

I rented a seismograph to a well-known blasting consultant in the northwest (now deceased) for recording blast vibration along a railroad right of way adjacent to Bonneville Dam. He called me and indicated that my instrument was incorrectly calibrated and wanted it replaced. After I did so, he called again and wanted the replacement unit changed because this was also reading high. He further informed me in no uncertain terms that he was well qualified in blast vibration prediction and that the high readings were well above what he had calculated for the blasting. I sent him another unit. When I received the second unit back, I noticed that the most recent recorded event was still in the instrument’s memory. When I printed it, I was amazed at the almost perfect sinusoidal waveform on the vertical channel, which incidentally was also the highest peak recorded. I had never seen a blast waveform that was that perfect. It was almost as if someone had recorded the motion of a tuning fork. I didn't think I would get very far talking with the consultant, so I called the contractor on the job. He investigated and found that the consultant had been setting the geophone on the end of a railroad tie! No wonder he was getting high readings. In this instance, the monitoring method was faulty and the data was bad, period.

In another instance, while I was assisting a contractor with his bid on a project, I came across blast vibration data provided by the owner in the bid package. The data had been collected by the owner's personnel on an earlier project at the site and was in tabular form, but it included no waveforms. As I went over the data it was obvious that the vibration levels had reached the upper limit of the seismograph range selected and the range had not been reset to a higher level. The vibration levels were almost constant and were too low for the varying distance and the explosive loading involved. The waveforms obviously would have shown clipping, but no waveforms were provided. In this instance, the data was bogus. The sad part was that the data was provided to potential bidders so that they might use it for blast vibration predictions in formulating their bids.

At the Bullfrog Mine near Beatty, Nevada, I had the opportunity to record blast vibration data and, at the same location, ground motion generated by nuclear tests at the Nevada Test Site at Mercury. Environmental groups had been trying to shut the mine down and were using as their argument potential damage to structures in Rhyolite, an adjacent ghost town. We were able to show that there was more ground motion generated in Rhyolite by the nuclear events at the Nevada Test Site than from the mine blasts and, for at least a while, the predictors of doom were silenced. While there, I had the opportunity of going over blast vibration tapes that a previous consultant from Las Vegas had recorded on site. One particular recording was a bit puzzling. He had recorded a vibration intensity of 0.01 in/sec at a frequency of 100 Hz at a distance of some 3000 feet from one of the mine blasts. Those of you who record quarry or large construction blasts at a distance would intuitively know that a frequency of 100 Hz would be quite high for blast vibration recorded at 3000 ft.

Being a curious sort, I analyzed this further. The instrument that recorded the blast sampled at a rate of 1024 samples per second per channel, which is fine. The problem was that only one channel exceeded the set trigger level of 0.01 in/sec and then only for an extremely short period. The seismograph took the few samples that were above the trigger level and calculated a vibration frequency of 100 Hz. In this instance, the vibration intensity of 0.01 in/sec was probably accurate, but the frequency was bogus. The Las Vegas consultant, assuming he was reasonably experienced and should have known better, signed the report as being factual anyway.

While visiting a powerhouse project in Central California, I witnessed a tunnel blast in very close proximity to the powerhouse. Rock that was in contact with the powerhouse wall was being blasted. I recorded the event with a seismograph that could record a 15 second event at 1024 samples per second per channel and obtained reasonably accurate data. Another seismograph located nearby (but from a different manufacturer) recorded vibration that was approximately twice the levels that I had obtained. The tape on that unit showed a high frequency wave superimposed over a low frequency waveform, indicating the probability of aliasing in the processing of the data. (Recording on a flexible, partially detached portion of a structure may give similar waveforms, but in this instance both geophones were anchored to the powerhouse floor.) Aliasing can occur in digital data processing when the frequency of the recorded data exceeds half the sampling rate of the instrument. In this particular model seismograph, when a 15 second duration was selected, rather than using more memory and retaining the 1024 samples per second rate, the sampling rate was lowered by 2/3 to 341 samples per second. The vibration frequency was probably in the range of 300 to 500 Hz and the resulting aliasing by the seismograph's internal program yielded bad data. In this instance, the engineers would have shut down blasting if we had not shown them good data from the newer unit and been able to explain the problem that occurred with the older one. The balance of recording at this project was done with instruments that maintained the higher sampling rate regardless of duration and, additionally, utilized an anti-aliasing filter when necessary. Unfortunately, the type of unit that presented bogus data here (the same type of unit as used in the previous Bullfrog Mine instance) is still in use at some locations. The data can be acceptable, but only if the recording is set for 5 seconds and vibration of 100 Hz or less is recorded.

There have been numerous other instances where the recorded data just didn't match up with the intensities or frequencies that were anticipated. From experience, you should know approximately what results you expect to obtain from your instrument. Don't just accept unusual readings as factual. Yes, they might be accurate, but investigate anyway and, if necessary, add whatever notes are needed to explain the discrepancy. You need to have accurate data for your predictions and good data will be invaluable to you and your consultant if a problem develops down the road.