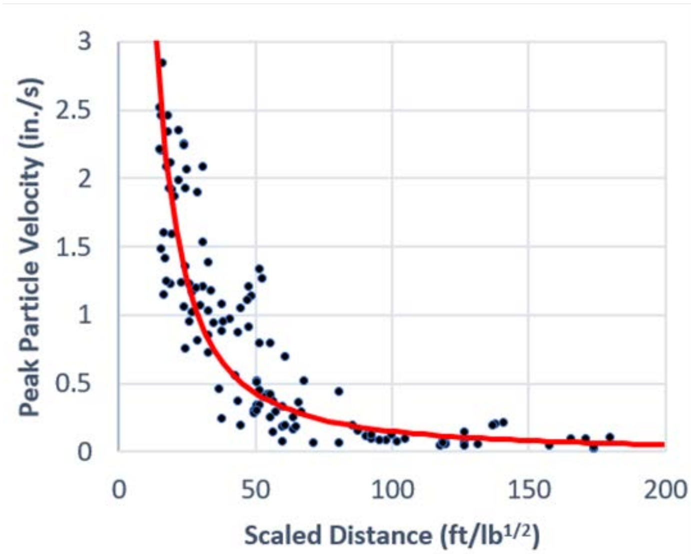
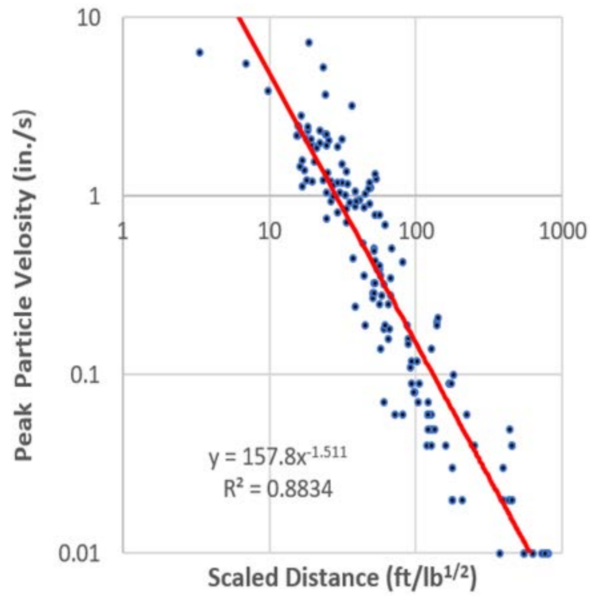
Newsletter #19b

Challenges of use of standard log-log presentation of measured decay or attenuation of peak particle velocity with scaled distance





Figures 1 (left) and 2 (right) compare arithmetically (left) and logarithmically (right) graphed attenuation of measured surface coal mine PPVs from 8507's Table 1 to demonstrate the ability of the arithmetic plot to convey more directly the rapid decay of ground motion with distance.

While plotting scaled distance attenuation in the traditional log-log form like Figure 2 on the right allows display of data that can range three or more orders of magnitude, it has several detrimental aspects. Most importantly a log-log graph is undecipherable by the general public and fails to convey the rapid decay of peak particle velocity (PPV) with distance as does Figure 1 on the left. To put this rapid decay into perspective, consider a 100 lb per delay surface coal mine shot. According to US RI 8507 the expected value equation [$119(R/W1/2)^{-1.52}$] indicates that peak ground motions from a 100 pound delay surface coal mine blast would decay to 0.5 ips after traveling only 360 ft. For typical quarry and construction bench blasting, Oriard's 90 % upper bound attenuation equation of $242(R/W^{1/2})^{-1.6}$ indicates that a 5 pound delay would decay to 0.5 ips after traveling only 110 ft (Hendron and Oriard, 1972) .

Another challenge with the traditional log –log scaled distance graph is that often different shot geometries and loading will be plotted on the same graph as is the case for Figure 10 in 8507, which results in the scatter. Scaled distance graphs are best employed with shots that are only slightly different and involve similar shot geometry, initiation timing and geology. The most accurate attenuation graphs are obtained with many seismographs for one shot rather than many shots with one seismograph because with one shot, all of the shot geometry and loading are the same.

Consider the shots from 8507 Figure 10 with scaled distances of 30 ft/lb1/2+/-1 or 20-31 tabulated in Table 1 below. Shots 65-67 involved detonation of 70 times the explosive weight per hole than shots 179 and 199. The absolute distances for 66-67 were some 7 times those for 179 and 199.

Differences in shot geometry, loading, and geology are likely causes of the differences in PPV's by a factor of 2 at the same scaled distance.

	Table 1 Shot Infromation for 29<SD<31 from 8507					
shot	W total	W/delay	SD	PPV	# holes	distance
	lbs	lbs		ips		ft
3	7,800	650	29	1.89	12	739
67	13,540	1,900	29	0.81	7	1264
65	15,700	2,200	30	1.06	7	1407
179	2,145	33	31	2.08	65	178
66	15,800	1,900	31	1.53	8	1351
199	1,200	30	31	1.20	40	170

One of the most important factors that is overlooked by reliance on a "typical" scaled distance attenuation relation to guide blast design is the effect of relief. Relief is necessary to allow expansion of the fragmented rock so that the explosive energy is consumed in fragmentation rather than propagating outward as ground motion. It is provided by a combination of detonation timing and openings or surfaces to which the fragmented rock can move. Several obvious cases come to mind where scaled distance predictions of typical ground motions may not be conservative. They are full face tunnel blasts, sinking shots, ditching or trench blasts for pipelines, and presplitting. All of these shot geometries are associated one or fewer surfaces to which the rock can expand during the fragmentation process.

Description of the details of these poorly relieved shots illustrates why they, and others like them, are likely to produce greater ground motions than predicted by "typical" scaled distance attenuation relations. Full face tunnel shots and sinking shots have only one surface for expansion of the fragmented rock. Large open "relief holes" into which the fragmented rock may expand are often added to tunnel blast deigns and sometimes to sinking rounds. Sinking shots are necessary in quarrying and mining to reach a new level. They generally produce greater ground motions at a given scaled distance because unlike bench shots with two or three faces toward which the rock can expand, there is only one surface, the horizontal. There is little relief along a trench blast and the only surface available is the horizontal surface. After a trench blast the fragmented rock is often seen mounded above the trench. Greater relief can be provided by only detonating a few holes at a time and then clearing rock from the trench to allow room for expansion of shot rock during the next blast. Presplit shots present a special case in that there is to be no fragmentation, only a crack between the holes.

Often scaled distance attenuation relations are presented as representing the physics of the fragmentation process when they are at their heart only an empirical method of presenting field measurements that only takes into account two factors, distance and explosive energy released per instant. They do not explicitly account for transfer of the energy to the surrounding rock, the subsequent fragmentation which is dependent upon rock type and jointing as well as dynamic wave interaction and gas pressurization, propagation of differing wave types though differing geologies, etc. Progress on prediction of both fragmentation and propagation ground motion will be made most efficiently with physics based methods that account for all of the above mentioned parameters.

References
Hendron, A.J. and Oriard, L.L. (1972) Specifications for Controlled Blasting in Civil Engineering Projects, Proc. First American Rapid Excavation and Tunneling Conference, SME, Littleton, CO