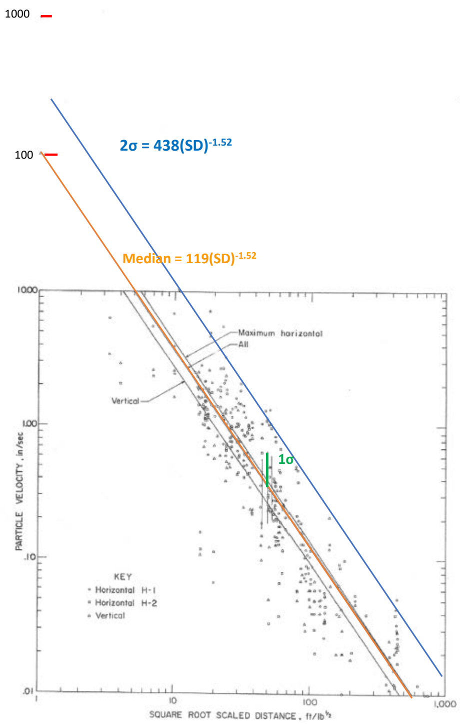
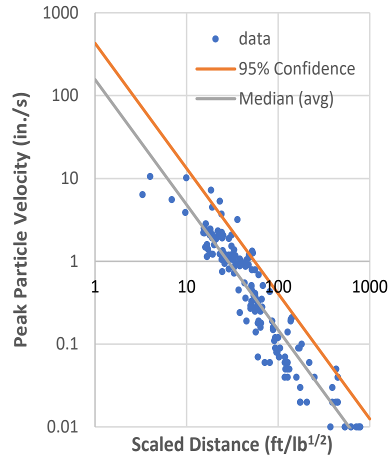
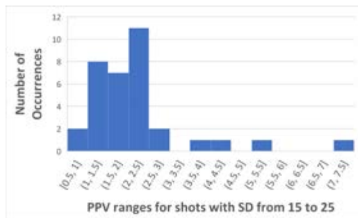
Newsletter #19

Scaled Distance Relationships in 8507 and the

Origin of the High Confidence Equation PPV = $438(ft/W^{1/2})^{-1.52}$







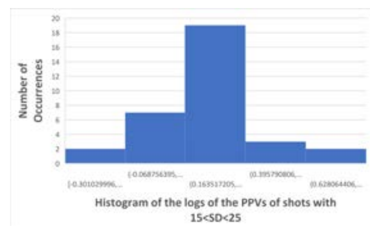


Figure 1 (left) 8507 Figure 10 with construction to show that the high confidence line, $438(SD)^{-1.52}$, for "total" is 2 standard deviation (σ) bars above the best fit line, $119(SD)^{-1.52}$ Figure 2 (upper right) PPV of coal shots in Table 1 of 8507 with 95% confidence line with standard error calculation for logarithmically skewed data. Figure 3 (lower center) Histogram of PPV of shots with 15<SD<25 showing the skewed or unsymmetrical nature of the data Figure 4 (lower right) Histogram of log10 of PPV for shots with 15<SD<25 showing the symmetrical nature of a "normal" distribution.

This newsletter explains the origin of the Siskind et al (1980) recommendation that "As alternatives to monitoring or for statistical predictive purposes, the maximums represented by the envelopes (e.g. fig 10) or two standard deviations from the mean can be [conservatively] used"; however, it is now recommended that all blasting be monitored with seismographs to provide quantifiable information.

Figure 1 illustrates how the **high confidence attenuation relation, PPV = $438(R/W^{1/2})^{-1.52}$**, is derived from Figure 10 in 8507. Siskind et al (1980) explained that "two standard deviations of the summary data in Figure 10 should leave 2.5 percent of points outside of the upper limit". **One standard deviation** is plotted vertically on Figure 10 and highlighted in **green**. The blue high confidence line intersects a point 2 times the height of the green one standard deviation and has the same slope (-1.52) as the **best fit line** defined in 8507 Table 3 for "All Bureau of Mines Coal Mine Data – Total". As explained on pages 54 and 55 of my book Construction Vibrations, the constant (KSD) in the power function equation ($KSD*(SD)^{-1.52}$) is the intersection of the high confidence line and $R/W^{1/2}$ (hereinafter SD) = 1. Intersections of the best fit and high confidence with SD = 1 occur at approximately 119 and 438.

The scaled distance (SD) versus peak particle velocity (PPV) graph in Figure 2 was obtained with Excel by plotting coal SD-PPV values from Table 1 in RI 8507 with the scatter function and logarithmic axes. PPV was the largest component for each shot in Table 1. The largest component is the assumed meaning of "total" in RI 8507. The best fit line through the median of the data and its power function equation is obtained by choosing "power" for the trend line. As shown in Figure 3 by PPVs between SD of 15 and 20 are clustered about small PPVs in a skewed fashion, while as shown in Figure 4, their logarithmic values are evenly or "normally" distributed about the expected value.

Without a graph, equations of lines of known confidence shown in Figure 2 can be found from the log – log or power function best fit attenuation relationship or trend line. They will have the same slope as explained above. The constant (KSD) in the attenuation relationship ($KSD*SD^{-slope}$) for 95% confidence is found by multiplying the KSD of the best fit or median trend line by 10 raised by the power of (1.645 times the standard error, SE) or

$$KSD_{best\ fit}*10\hat{}(1.645*SE)$$

Where the SE is the standard error of the data about the best fit line. The standard error (SE) is found through the following equation

$$SE = [(n/n-2)*(1-cc^2)*\ \sigma_{logy}{}^2]^{1/2}$$

where n is the number of points, cc and σ_{logy} are the correlation coefficient of SD with PPV and standard deviation of PPV in log form. (Benjamin and Cornell, 1970). The correlation coefficient (cc) of log10 SD and log10 PPV data is calculated with the Excel function CORREL. The standard deviation, σ_{logy}, is that of the deviation of log10 PPV (Y axis) about the trend line and is calculated with the Excel function STDEVP with the log10 PPV data. Given that all the above construction and relationships are described in terms of the logarithmic values, it make sense to make all calculations with the logarithmic values.

What degree of confidence is represented by the high confidence equation, $438(SD)^{-1.52}$? As quoted above, Siskind et al (1980) indicates that 97.5% (100-2.5%) of the data would fall below the 438 line. The 95% confidence line in Figure 2 was calculated with a 1.645 coefficient, which defines the number of standard deviations (of normally distributed data) above the expected value ($157.86(SD)^{-1.511}$) that will exceed 95% of the “total” data from RI 8507. Its equation is $427.61(SD)^{-1.511}$. Some 7 PPV’s (or 4.4% of the 159 data points) exceed either $438(SD)^{-1.52}$ or $427.61(SD)^{-1.511}$. For all practical purposes, the 438 attenuation relationship provides a 95% confidence for coal mine shots that fall within the parameters of Table 1. The 7 points (in order of exceedance) were shots 181, 7, 193, 110, 6, 100 and 122.

What scaled distances can be employed with 95% confidence? Equations $438(SD)^{-1.52}$ and $427.61(SD)^{-1.511}$ respectively return scaled distances of 86 and 87 for a PPV of 0.5 ips and 55 for a PPV of 1.0 ips. Thus Siskind et al’s recommendation of SDs of 90 and 55 are statically appropriate; however as stated in the beginning, all blasting should be monitored with seismographs to provide quantifiable information.

Table 1 from 8507 has been reproduced in Excel form and will be made available for study in the Listserv Archive on the ACM web site. While it has been possible to verify the origin and meaning of the 95% confidence (438) equation, the median or mean (119) equation has not been reproduced with the definition of total as the PPV for all or total of the shots.

References

Benjamin, J.R. and Cornell, C.A.(1970) Probability, Statistics and Decision for Civil Engineers, McGraw-Hill Book Co., New York, 684 pgs

Siskind, D. E., Stagg, M. S„ Kopp, J. W., and Dowding, C. H. (1980b), "Structure Response and Damage Produced by Ground Vibrations from Surface Blasting," Report of Investigations 8507, U.S. Bureau of Mines, Washington, DC.

This newsletter was written to address two issues. Further explanation of the origin of the 438 attenuation equation, which was brought to my attention by Mike Mann. Correcting the definition and calculation of the confidence equations in my book Construction Vibrations, which was brought to my attention by Kristian Murfitt.