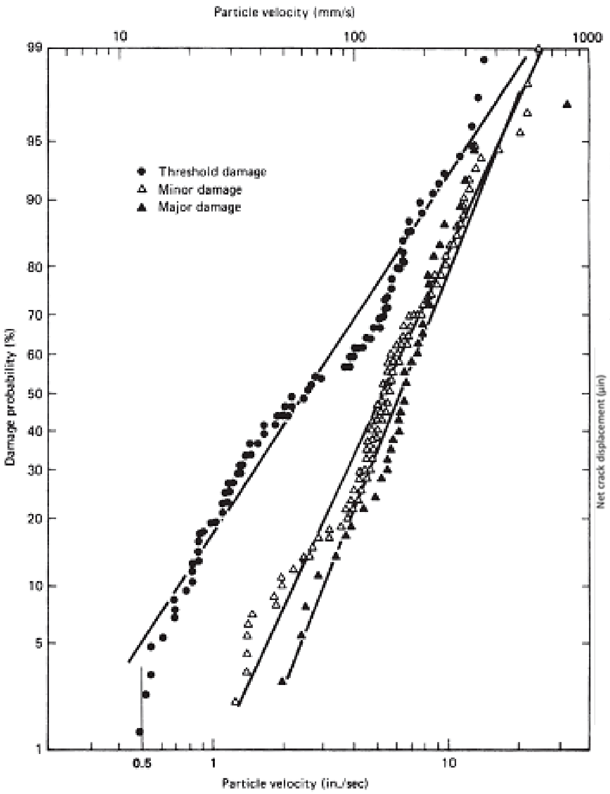
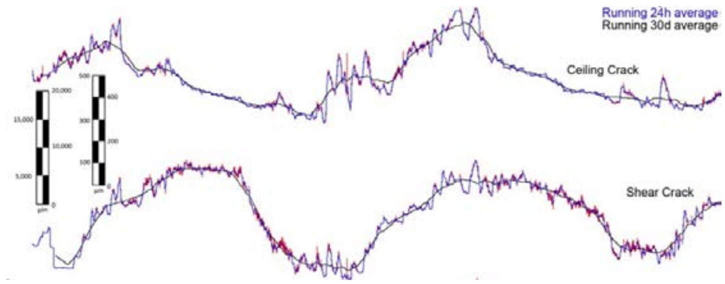
CONST-VIBRATION Newsletter #17
Micro-meter crack response verifies
zero probability of cracking below peak particle velocities of 12.7 mm/s (0.5ips)





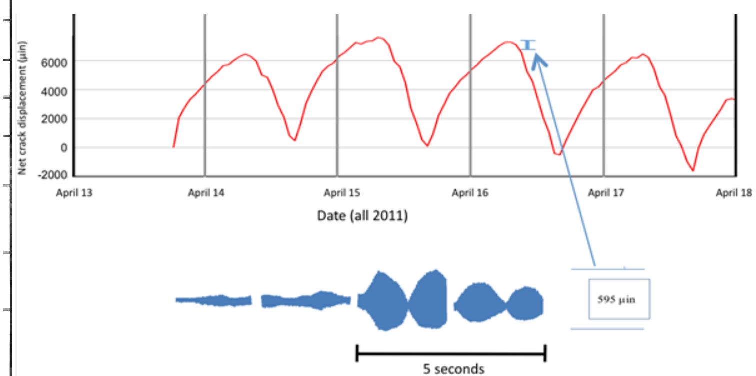


Figure 1(left) Probabilistic analysis of the threshold of cosmetic cracking demonstrates the absence of data below a peak particle velocity (PPV) 12.7 mm/s or 0.5 ips and leads to a conclusion of zero probability of cracking below 12 mm/s for even low frequency excitation. (Siskind, 2000).
Figure 2(upper right) Shear & ceiling crack response of more than 262 µm (10,500 µ-in) over a *two* year weather cycle where a quarry blast with a PPV of 13 mm/s (0.52 ips) produces 10 µm crack response demonstrates why blasting would produce insufficient distortion to exceed that of natural causes.
Figure 3 (lower right) Daily climatological crack response (red) of 150 µm (6000 µ-in) compared to 15 µm (595 µ-in) induced by a vibrating roller (blue) producing a PPV of 12 mm/s (0.48 ips) at the wall containing the crack.

Verticality at 0.5 ips (12 mm/s) of the relationship between cosmetic cracking (damage) probability vs particle velocity in Figure 1 (Figure 59 from USBM RI 8507 study) implies that the probability becomes zero at lower peak particle velocities. Results of this study with visual inspections for cracking immediately before and after blasting events were analyzed with the assumption that every cracking observation excludes the possibility of non-cracking at a higher particle velocity. Calculating probability of cracking as the percentage of observations at lower levels of velocity results in the log-normal scaled plot of the probability of cracking versus particle velocity in Figure 1.

This zero probability conclusion was reached by Siskind in his summary book (Siskind, 2000). As shown there is a lower limit of PPV of 12.7 mm/s (0.5 in/sec) below which no cosmetic or threshold cracking (or extension of hair-line cracks) has been observed from blasting. Data in this low PPV region were reported by Dvorak (1962) for low frequency (~ 4 Hz) excitation of older plaster and lath walls. The seminal RI 8507 study was not able to detect even threshold cracking at PPV's below 20 mm/s (0.79 ips) with even a lower level definition of the threshold of cracking then used in previous studies. Since publication of RI 8507 in 1980 only one case of cosmetic cracking at a low PPV has been observed. It was observed in a plaster and lathe walled house with a PPV of 37 mm/s (1.46 ips) that included a 6 Hz driving pulse with a PPV of 13.4 mm/s (0.53 ips). See Newsletters 5, 14 and 15 for further discussion of the implication of driving pulses.

Zero probability of cracking (including low frequency excitation discussed in Newsletters #13) is most likely the result of the insignificance of vibratory distortion and related crack response compared to that induced by naturally occurring climatological effects. As discussed in the previous Newsletter # 16, for 14 cracks driven at PPV's of 11 mm/s (0.44 ips) and greater, the average ratio of vibration to climatologically induced micro-meter crack response is only 0.146. One of these cracks was in a concrete block or CMU structure, so this ratio is not just the result of the response of wood frame structures. Thus natural causes produce structural distortion and related crack response that is – on average -- some 7 times greater than that produced by vibratory excitation even at ground motion levels that are nearly 4 times that of the DIN recommendations.

Measurements of crack response shown in Figure 2 over a two year period in the Sycamore, IL test house further demonstrate the overwhelming effect of climatological effects. (Abeel, 2012). The zero to peak (~ one half peak to trough) yearly cycle response is over 260 µm for the shear crack, which is about the thickness of three sheets of paper. Anyone with a wall-papered house (like my 1908 vintage home with large settlement cracks) where wall paper spans a crack can attest to the large yearly expansion and contraction of cracks that bunches the wall paper at the crack. For comparison, the Sycamore quarry blasts that produce PPVs of 13 mm/s (0.52 ips) at the test house produce only 10 µm of ceiling crack response, which is only 1/26 or 4% of that produced by the yearly weather (and home heating) cycle. Deactivating heating produced another, separate cosmetic crack. At that time the shear crack had expanded more than 1.2 to 1.3 times the maximum recorded (Dowding et al, 2015)

Vibration-induced crack response has to be large to overcome the continual, daily opening and closing of cracks like that shown **in red** in Figure 3 to produce a permanent change. This large daily, climatologically-induced change in crack width of 150 µm (6000 µ-in) was measured across a crack on a south facing stucco wall in Albuquerque, NM. Also plotted **in blue** to scale (amplitude, not time) for comparison is the 15 µm (595 µ-in) response of that crack to a PPV of 12 mm/s (0.48 ips) produced by a large roller vibrating at 35 Hz in front of the wall containing the crack. The average rate of opening and closing of this crack is 150 µm/12 hrs or 12.5 µm (500 µ-in.) per hour. Thus changes in temperature and humidity opens or closes the crack in 1.2 hours (15/12.5) the same amount as will one passage of a large roller producing a PPV of 12 mm/s.

These examples demonstrate that crack responses to PPVs at 12 mm/s (0.5 ips) fall far enough below responses to daily effects that no cracks are produced to be observed below that limit. This lack of crack observations led to the probability of cracking v PPV graph in Figure 1 to turn vertical at 12 mm/s or 0.5 ips.

References

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Dowding, C., Lueker, J. & Abeel, P. (2015) Instrumental Detection of a Climatologically-Induced Cosmetic Crack in Wall Covering, Proceedings of the 41st Conference of the International Society of Explosive Engineers, Cleveland, OH. Also available at http://www.civil.northwestern.edu/people/dowding/acm/publicationsACM.html

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