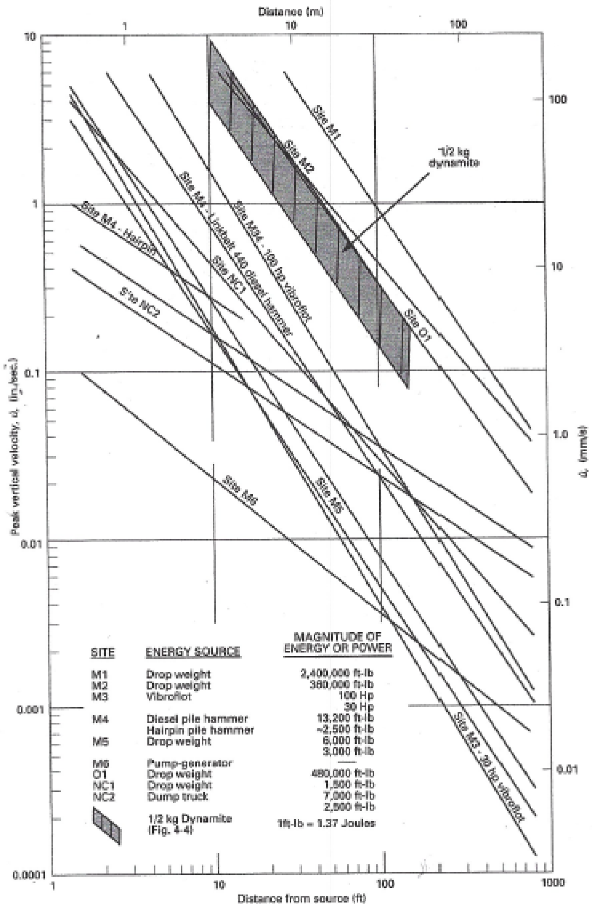
CONST-VIBRATION Newsletter #31

Earthquakes Differ by Orders of Magnitude from Construction Vibrations in Energy, Dominant Frequency and Waveform



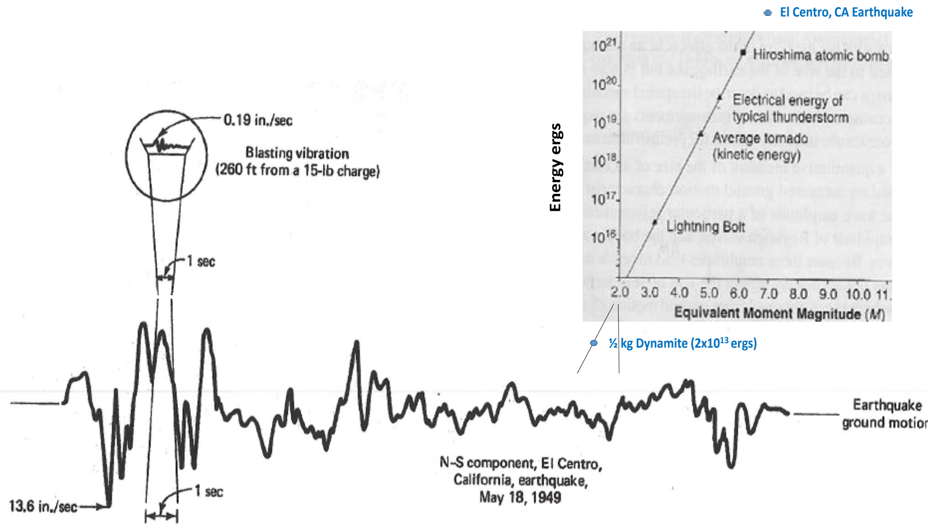


Figure 1 (left) Peak particle velocity vs distance compared to various construction sources and their associated intrinsic energy (in ft-lbs) (after Woods and Jedele 1985). Figure 2 (above) compares a Richter Magnitude (~ Moment Magnitude) 7, El Centro, CA, earthquake ground motion with that of a blast induced ground motion produced by ½ kg of explosive. Inset above Figure 2 (after Kramer, 1996) compares the intrinsic energy of the El Centro earthquake (10^{22}ergs) and the ½ kg of explosive (10^{13} ergs). One (1) erg = 7.5 x 10^{-8} ft-lbs. The M1 dynamic compaction event was produced by a 15 ton weight dropped 25 m (80 ft).

Appreciation of the large differences between construction and earthquake induced ground motions requires understanding of the orders of magnitude differences in size (magnitude), dominant frequency, intensity (effects at a given location), and design techniques. It also requires three newsletters to more fully relate these two important dynamic phenomena than was accomplished in my book Construction Vibrations. The following two newsletters will address intensity and design techniques. This addresses energy and dominant frequency, and waveform.

Size or more accurately magnitude describes the intrinsic or available energy of the phenomena. As described by Oriard (2002) earthquake magnitude was developed in the United States by Charles Richter to describe the "size" of an Earthquake by the relative acceleration amplitude, which at the time had a range of 4 orders of magnitude. To compress the data, a base 10 logarithm scale was employed. Thus an increase in "Richter Magnitude - RM" say from 5 to 6 represents an order of magnitude increase in acceleration. Later work found that an increase in an order of magnitude in acceleration required an increase in energy of about 32. This increase can be seen by the difference in energy between a RM 5 and 6 in the inset to Figure 2 above.

Intrinsic construction vibration energy can be calculated as shown in Chapter 16 of Construction Vibrations. Probably the easiest form of construction induced vibration to understand its intrinsic energy is that of dynamic compaction, where heavy weights are dropped onto loose sands and silts for compaction. Energy in foot-pounds (ft-lbs) or ton-meters is easy to calculate as it is simply the weight (mass) times the distance dropped. The equivalent values for various construction sources are given in the inset to Figure 1 in ft-lbs (Woods, and Jedele, 1985). Even one of the largest drop weight and height dynamic compaction machines ever employed only produced 3 x 10^{13} ergs. For comparison a RM 4 magnitude earthquake involves 3 x 10^{17} ergs, some 4 orders of magnitude or 10,000 times more energy.

As will be discussed in Newsletter #32, intensity of the ground motion (the effect or degree of response of humans or structures) depends upon interaction of the energy source and the medium in which it is applied or released and the distance away from the source the receiver is located. As shown Chapter 16 of my book, the stiffness of the medium plays a role in the percentage of the intrinsic energy that is converted to ground motion. Figure 1 displays the effects of these two considerations through the comparative attenuation relations.

Time histories of earthquake and construction blast induced ground motions in Figure 2 demonstrate other consequences of the differences: displacements, frequency content, and duration of the ground motions. Damaging earthquakes involve displacements that can be seen by eye as they approach and measured with a yard (meter) stick. Whereas construction vibration displacements are no more than the thickness of pieces of paper. Associated displacement is PPV/2πf, where PPV is the peak particle velocity and f is the dominant frequency. Consider the El Centro design earthquake in Figure 2 above. Dominant frequency is around 0.2 Hz; thus the ground displacement could be as high as is (13/(2*3.15*0.2) =) 10 inches. The blasting vibration of 0.19 in/sec at 30 Hz produces a ground displacement of (0.19/ (2*3.14*30) =) 0.01 inches, 3 orders of magnitude lower. The effect and importance of dominant frequency for comparing earthquake and construction accelerations are well described by Oriard (2002) and will not be repeated here. Suffice it to say, because of the large difference in dominant frequencies, neither peak acceleration nor peak particle velocity, should be employed for comparison of the effects of the two different phenomena in inducing building strains. This comparison is best achieved with response spectra induced by the full wave form, which will be addressed in Newsletter #33 in the discussion of design techniques.

References

Oriard, L. (2002) Explosives Engineering, Construction Vibrations and Geotechnology, International Society of Explosives Engineers, Cleveland, OH, 680 pgs