Newsletter #11

Crack Response of Nevada Test House to Vibrations Induced by Construction Equipment Verifies Conservatism of Limits for Continuous Cyclic Excitation

Crack responses to ground motions produced by construction equipment show that higher peak particle velocities are necessary to cause the same level of distortional response when excitation frequencies increase. This newsletter is the third of three (#9, #10 & #11) devoted to continuous cyclic excitation, and are best considered together.

Event	Peak Particle Velocity (ips)	75% Peak (ips)	# of Significant Peaks	50% Peak (ips)	Length of Significant Excitation (sec)	Peak SDOF Frequency (Hz)	Dominant FFT Frequency (Hz)	Wavelength (ft)	Crack Displacement '(#, Location)' (µin)
Blast 15	0.345	0.259	7	0.173	0.65	20	23	435	90 (3, Conn)
Trackhoe #2	0.080	0.060	2	0.040	0.14	25	22	182	63 (2, LV)
Trencher #2	0.069	0.052	1	0.035	0.08	70	54	74	15 (2, LV)
Small Roller #3	0.147	0.110	10	0.074	2.7	30	32	125	48 (2, LV)
Large Roller #3	0.237	0.178	23	0.119	4.50	24	24	167	110 (2, LV)

Table 1. Summary of Ground Motions Produced by and Crack Response to Reciprocating or Vibratory Construction Machinery.

Figure 1 (L-R) Test House w/ Hitachi trackhoe, Tesmec chain trencher, Dynapac small and Ingersall Rand large vibrating rollers.

As discussed in newsletter #10 experimental results from the continuous, cyclic, distortion of the test house described in Newsletter #9 can be applied to construction activities that produce repeated motions such as vibratory pile driving, vibratory roller compaction, etc. High operational frequencies of construction equipment provide an additional level of conservatism to the observation of cosmetic cracking only after 52,000, 7 Hz pulses at peak particle velocities (PPV) of 12.7 mm/s. Higher frequency excitation ground motions (25-40 Hz) produce lower structural strain than cyclic excitation of the test USBM house (Stagg et al 1984) at its natural frequency of 7 Hz. Thus they are less likely to produce cosmetic cracking.

This principle that excitation frequencies closer to the responding structure’s natural frequency produce larger distortions and thus larger strains can be demonstrated with crack response to cyclic excitation of the test house in Nevada described in Newsletter #10 (Snider, 2003). Response of Crack 2 in the Nevada test house to construction equipment induced ground motions demonstrates the importance of excitation frequency in determining structural response. Ground motions produced by four different types of construction equipment were measured and are described in Table 1; 1 and 2 pulse excitation from a chain driven trenchers and trackhoe bucket excavator, and continuous cyclic excitation with large and smaller vibratory rollers.

Ratios of crack response divided by PPV show that those sources with higher dominant excitation frequency produce the lowest crack response. Table 1 compares PPV with dominant frequency and other wave form descriptors. Of particular interest are the PPV, dominant frequency and crack response. Since different cracks in differing structures have differing sensitivities to excitation and thus cannot be compared, only crack 2's responses to four differing forms of excitation will be analyzed.

Pulses and waveforms are quantified in Table 1 by the length of the time history that contains the overall peak. As shown in Snider (2003) the trackhoe event 2 had 2 significant pulses with significant excitation lasting 0.14 seconds. The single pulse event from the trencher was believed to result from the trencher intersecting a location of more heavily cemented caliche. The two roller events caused the most sustained vibration. Small roller event 3 contained 10 significant pulses with a 2.7 second excitation, and large roller event 3 contained 35 significant pulses over 4.3 seconds of excitation. As discussed in Newsletter #10, peak excitation only lasts a short period of time as the roller moves past the structure. Thus the number of pulses with the PPV are limited.

Ratios of crack 2 response divided by PPV in Table 1 decreases from 787 to 288 as the frequency of excitation increases from 22 to 54 Hz:

Construction Machine	Dominant Frequency (Hz)	Response (µin)/PPV(in/s)
Trackhoe	22	787
Large Roller	24	464
Small Roller	32	326
Trencher	54	288

This declining trend of relative response with increasing excitation frequency is important for vibrating rollers with variable vibration frequencies. The larger roller with it lower excitation frequency produced larger crack responses when normalized for PPV than did the smaller roller with higher excitation frequencies.

References

Snider, M.L. (2003) Crack Response to Weather Effects, Blasting, and Construction Vibrations, MS Thesis, Department of Civil and Environmental Engineering, Northwestern University. Available on civil.northwestern.edu/people/dowding/acm/publicationsRollers.html.