CONST-VIBRATIONS Listserv Newsletter #9

Not even repetitive vibration at 12.7 mm/s (0.5 ips) can produce cosmetic cracking

52,000 cycles of repeated vibratory twisting of an entire house at strains equivalent to those induced by surface coal mine blast-induced ground motions with a PPV of 12.7 mm/s (0.5 ips) were required to produce nail pops and a crack in a drywall tape joint.

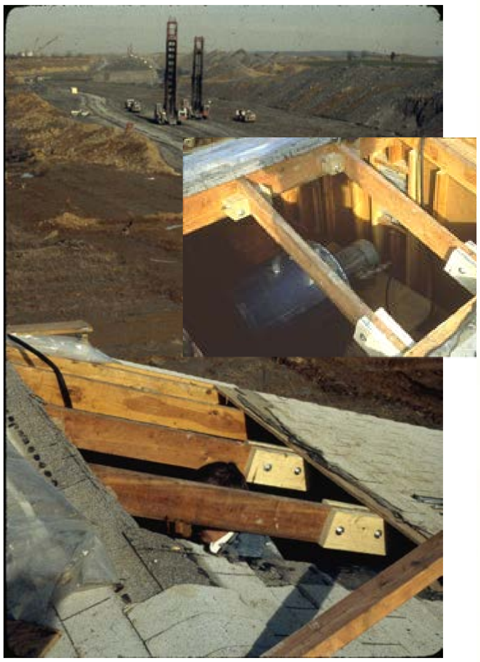

TABLE 12. - Cracks observed after shaker excitation

Shaker vibration equivalency[1] and crack description	Number of cycles at cracking	
	Run	Total[2]
Run 1, ~ 0.5 in/s:		
Entryway tape joint crack............	52,000	56,000
Crack in joint compound over nailhead in master bedroom..................	52,000	56,000
Fireplace mortar joint crack extension[3]..........................	52,000	56,000
Run 2, ~ 0.5 in/s:		
Chimney trim broken loose from siding[3].............................	>1	>108,500
Mortar joint crack at top of chimney.	>1	>108,500
Run 3, ~ 0.3 in/s:		
Brick veneer mortar joint cracks.....	15,000	229,500
4 cracks in joint compound over nailheads...........................	25,000	239,000
Run 4, ~ 0.75 in/s:		
Vertical crack through brick veneer mortar.............................	14,500	293,500
Cracks in joint compound over nailheads...........................	60,000	339,500
Basement block mortar joint crack extensions..........................	>1	>339,500
Run 5, ~ 1.0 in/s:		
Brick veneer mortar falling out......	>1	>339,500
Basement block mortar joint crack extensions..........................	>1	>339,500
Crack in wallboard...................	22,000	361,500

[1]Based on envelope response from plot of ground vibration versus structure motion at site A_4 (fig. 13), high corner, east wall, as structure was at resonance.

[2]At vibration equivalency of ~ 0.5 in/s; including cycles induced by blasting and frequency sweeps.

[3]Cracking suspect because superstructure was racked against normally foundation-driven fireplace.

Figure 1 left; Photographs of the test house and mining activity showing the installation of the eccentric shakers

Table 1 right; Table 12 from RI 8896 describing the cosmetic cracking and the number of continuously repeated cycles at strains equivalent to PPVs of 12.7 mm/s (0.5 ips) to produce the smallest of cosmetic cracks

After sustaining some 128 surface coal mine blasts with peak particle velocities (PPVs) of up to 160 mm/s (6.5 ips) the test house was subjected to continuous cyclical torsional straining until further cosmetic cracking was observed (Stagg et al, 1984). Details of the cosmetic cracking induced by the 128 surface mine blasts was summarized in Newsletter #8. These 128 blasts themselves could be considered repeated vibratory events.

Continuous cyclical torsion straining was induced by eccentric basket shakers bolted to the attic floors at opposite ends of the house as shown in the two photographs in Figure 1. This equipment was borrowed from earthquake engineering researchers and is standard equipment employed to shake structures to induce dynamic responses. Eccentrically loaded baskets were rotated at the natural frequency of the test house, approximately 7 Hz, so as to produce forces in opposite directions at each end of the house. Sufficient masses were added to the baskets to produce enough force to produce displacements (and thus strains) in the house equivalent to those that has been measured when the previous surface mine blasts produced PPVs of 12.7 mm/s (0.5 ips)

Noise produced by strains induced by this continuous cyclical distortion was horrific. I was in the house during the first run described in Table 1 (copy of Table 12 from RI 8896), and was driven outside by extreme discomfort after 10 to 15 or so minutes. Those 15 minutes represented only some 6000 cycles (15*60*7 = 6300) or just 12% of the time or 52,000 cycles necessary to produce the crack in the entryway tape joint. Cracks in tape joints in the test house were cracks in plaster coated paper that spanned sheets of drywall.

These cosmetic tape joint cracks induced by more than 52,000 cycles of repeated vibratory excitation were observed in a structure already cracked by the surface coal mine blasts described in Newsletter #8. It had sustained PPVs of over 150 mm/s which induced the cracking described in RI 8896. Thus the structure was cracked at the time cyclic testing.

The 52,000 cycles represent a long time of repeated blasting or construction vibration and need to be put in perspective. Suppose a quarry blasted once a week and produced PPVs of 12.7 mm/s; 4 pulses in each blast had amplitudes o 12.7 mm/s; dominant frequency was low, 5 to 10 Hz. Even under these highly unusual circumstances, the quarry would have to operate some 250 years [52,000/(52*4=208)] to produce a cosmetic crack in a tape joint by repeated blasting.

These experimental results can be applied to construction activities that produce repeated motions such as vibratory pile driving, vibratory roller compaction, etc: however more explanation is required because operational frequencies of 30 Hz produce lower structural strain than 7 Hz excitation. Let's ignore for a moment this important distinction and suppose a vibratory roller passes by a house at a speed of 4 miles an hour (6 ft/sec), produces a PPV of 12.7 mm/s while passing the house. That means that any single location of a structure will only be subjected to at most 0.5 seconds or 15 pulses of peak excitation. Thus some 3,400 passes would be needed to produce 52,000 cycles of motion. Now let's address the response distinction; cyclic excitation at 30 Hz rather than 7 Hz produces lower structural strains, and thus the vibratory equipment would have to produce PPVs higher than 12.7 mm/s to reproduce the same strain history as induced in the test house with the 7 Hz excitation motions.

Future newsletters will further explain with measurements of structural response the distribution of distortion and thus strain induced by vibratory construction equipment as well as the lower response with higher frequency excitation. One newsletter will be required for each.

References

Stagg, M.S. Siskind, D.E., Stevens, M. G., and Dowding, C.H. (1984), Effects of Repeated Blasting on a Wood Frame House, U.S. Bureau of Mines Report of Investigations RI 8896, available from International Society of Explosive Engineers.