Newsletter #27
Measurement of Occupant Induced Crack Response Shows
Larger Incidence of Occupant- Induced than Blast-Induced Events

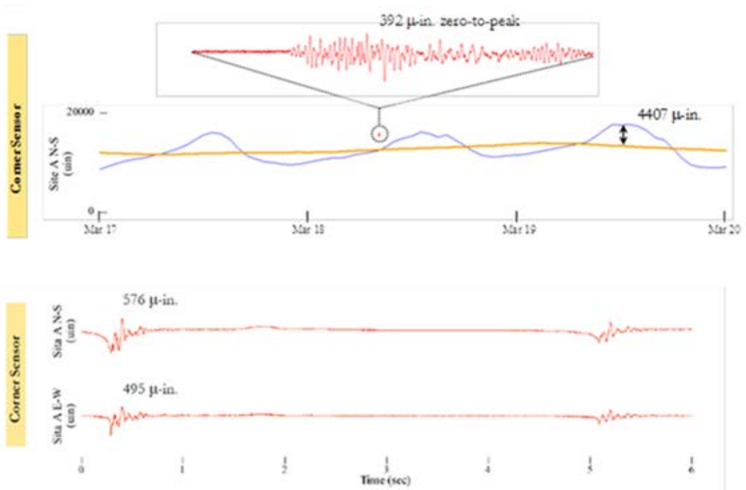

Figure 1 (left) Comparison of corner crack responses to, long term climate, and dynamic blast and occupant events. (Top left) comparison of a 10 micro meter (400 micro inch) blast induced crack response compared to the 100 micro meter (4000 micro inch) daily weather induced crack response. (Bottom left) same crack response of some 14 micro meter (575 micro inches) to occupant opening and closing of the front door located some 30 ft (10m) away
Figure 2 (right) Micro meter displacement gages deployed in the corner of the Naples FL house from which measurements in Figure 1 came. The north-south displacement sensitive gage is the uppermost.

This newsletter compares crack responses produced by occupant induced disturbances with those produced by quarry blast induced ground motions. A specialized instrumentation system triggered by wall motions as well as the typically scrutinized ground motions allowed this comparison to be made. This newsletter is the first of four that explore the implications of measurements of crack response to events produced by natural phenomena and human occupation. The fourth will compare of the probability of the causation of critical crack response by human occupation and external dynamic events.

These unique measurements were made at a heavily instrumented house near a quarry near Naples FL (Dowding & Meissner, 2010). This slab on grade house was recently constructed to modern insulation standards with concrete masonry unit (CMU) exterior walls. Triggering of dynamic crack response by any of the 8 velocity transduces on walls and ground outside and the air over-pressure transducer allowed recording crack response on a single, common time base. Heretofore little measured dynamic events such as thunder, music, door openings and closings, etc were recorded. Special triggering codes allowed identification of the first transducers to be triggered, and thus the source by proximity to the dynamic excitation.

Blast and occupant induced crack response employed in this newsletter are from the north-south displacements of the corner crack shown in Figure 2. This crack was located in a corner between an interior stick or stud constructed wall and the exterior CMU wall. North-south responses of this corner crack (in a direction perpendicular to the exterior CMU wall). This crack and this direction of the corner crack are employed to compare the effects of occupant and blast induced excitation because it had the largest responses to both types of excitation. Kaman SMU-9000 eddy current micro meter displacement sensors shown in Figure 2 were employed to measure the micrometer crack response. They have a resolution of 0.1 micro-meter (4 micro-inch), and frequency response of 10,000 Hertz (Hz).These displacement sensors measure micro meter changes in the crack width, which are referred to as crack response from here forward. The same gage measures both long term and dynamic response, at the same location across a crack. Thus the comparison between long term response and dynamic response can be made directly.

Dynamic crack responses are small compared to those induced by weather as described in Newsletters 16 and 17. Figure 1 compares the time history of the corner crack response to one of the larger blast induced events (red dot within the circle) with that induced by just the daily, temperature induced long term response (blue). Dynamic crack response is less than 1/10 the daily, temperature induced, long term crack response and had to be magnified just to be visible in Figure 1. The diminutive size of dynamic crack response compared to long term, climatological and seasonal response is typical and documented with dozens of case histories (Dowding, 2008). The time history of the north-south (NS) and east-west (EW) response of the corner crack from a door opening or closing event is shown in the lower half of Figure 1 for comparison. While the time histories of the NS response of the corner crack to door opening and closing is shorter than that to blast induced ground motion, its amplitude and frequency content are similar.

More than 300 crack responses to occupant induced opening and closing of two doors, recorded during three months, are compared in Table 1 with the 16 crack responses to blast induced ground motions recorded during 10 months from October through July. Door induced responses varied between 2 and 11 µm (80 to 440 µ in.). The doors were located some 10 to 12 meters from the instrumented corner crack in the living room. During these 10 month these 16 quarry blasts produced peak particle velocity ground motions of 1 to 4.5 mm/s (0.04 to 0.175 ips) and crack responses of 4 to 11 µm (160 to 440 µ in.).

These data show that over a 10 month period, there would be some 1000 occupant induced events producing crack responses that are similar to the 16 blast induced events. In grossly over simplified terms and all other things being equal, if a critical location on a wall were on the verge of cracking it would be 1000/16 times more likely that a door slam would provide the distortion necessary to crack the wall rather than blast PPV's of 2.5 mm/s (0.1 ips) . This series of four newsletters will end with a mathematically based procedure to employ these observation to calculate the probabilities.

Table 1: Comparison of Crack Response to Occupant Induced Door Opening and Closing with that induced by Quarry Blast Induced events.

Door Openings			Blast Induced Ground Motions		
3 Months of Observation			10 Months of Observation		
# events	Crack Resp		PPV	# events	Crack Resp
n	µm		mm/s	n	µm
1	11.43		2	1	5.08
5	7.62		1.9	1	4.06
4	6.65		2.9	1	4.57
10	6.02		2.8	1	9.96
23	5.38		2.5	1	8.66
20	4.7		1.3	1	3.81
36	4.24		2.3	1	4.57
45	3.48		2.4	1	6.2
85	2.84		1.5	1	5.59
88	2.29		3.4	1	4.57
317			1.3	1	7.34
			2.5	1	7.44
			1.8	1	12.4
			1.3	1	7.21
			2.2	1	8.23
			4.4	1	11.23
				16	

Systems able to trigger on structural or crack motions capture unusual events such the Space Shuttle flying over Naples while on approach to Cape Canaveral on 31 July 2009. The double pulse air overpressure wave and the crack responses are shown below in Figure 3. The largest blast induced air overpressure pulse was some 0.0007 psi and the shuttle's sonic boom was 0.002 psi, some three times greater. Interestingly the air overpressure pulse produced by nearby lightning strikes was on the order of 0.01 psi, five times greater than the sonic boom produced by the Shuttle. Since we don't know how the distance between the shuttle and the test house, other data such as that from the 1967 Air Force study by Wiggins described in Chapter 14 in Construction Vibrations should be employed to determine cracking potential of air overpressures.

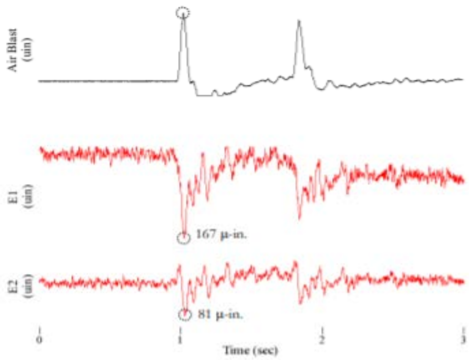

Figure 3: Air Overpressure wave and crack response to sonic boom produced by the space shuttle on 31 July 2009.

References

Dowding, C.H. and Meissner, J (2010) "Comparison of Micro-inch In-Plane and Out-of-Plane Response of Cracks to Blast Vibration and Weather" Proceedings of 36th Conference on Explosives and Blasting Technique, International Society of Explosives Engineers, Cleveland, OH, February 2010.