Background

This is Phase-II report of the response of a one-story residential structure in Naples, Florida, shown in Figure NFII-1. This slab-on-grade house has CMU exterior walls covered with stucco and wood interior construction with drywall finish. It is located adjacent to the Jones Limestone Quarry which generated blasts 25 times in the study period (Sep 1, 2008 through Sep 1, 2009) with peak particle velocities that ranged from 0.05 to 0.18 inches per second.

Phase II includes velocity response of the structure, crack response in both the in and out-of-plane direction, a cracked corner joint, and an uncracked drywall joint. Structural and crack response produced by ground motions from blasting are compared to those produced by thunder, occupant activity (door slamming) and environmental conditions (long term changes in temperature and humidity).

Phase II features an expanded instrumentation program, with several new crack sensors and velocity transducers to measure structural response as shown in Figure NFII-2. Long-term crack response is measured by accumulating crack data every hour as the average of a burst of 1000 samples in one second.
Context (left) and details (right) of the installations are shown in Figure NFII-3. Both cracks occur between two differing materials. The corner crack in the living room, shown in the top row, occurs at the concave corner between the CMU-stucco north wall and the perpendicular wood stud and gypsum drywall west wall. The interface crack in the kitchen-garage door shown in the middle row in Figure NFII-3 also occurs between the CMU wall on the left and the wooden, door frame and wall on the right. Both in and out of plane responses were measured across this highly responsive interface crack. The large response of this interface upon door closings in the house is indicative of the ineffective connection between the two components. The instrumented garage ceiling drywall joint is shown at the bottom of Figure NFII-3. Sensor D1 spans the joint and D2 is nearby on the full section drywall. They are installed on the attic, upper, or uninhabited side of the garage ceiling as can be seen in the center of the photograph on the left.

Long term crack response is compared to climatological effects in Figures NFII-4 and NFII-5. These data are assembled as the highly variable blue line. The thick, less variable red line is a 24-hour central moving average (CMA) of the hourly points which highlights the passage of weather fronts. The black, even less variable line is a 30-day CMA of the hourly points which will highlight seasonal trends. Response of the cracks in the living space (C1,E1,E2) is shown with the indoor temperature and humidity in Figure NFII-4. Long-term response of cracks outdoors and in the garage (A1,A2,B1,D1) are shown in Figure NFII-5. Environmental factors similarly affect both in- and out-of-plane crack response with in-plane response being slightly larger.

Responses to long term climatological effects of the uncracked, paper-thin (and thus weak) drywall joint are shown in Figure NFII-6. It was in the ceiling of an un-moderated garage and observations included hot, humid, summer months. These long term measurements, spanning some four months, show that uncracked weaknesses in wall covering are less responsive to long term, climatological effects than other cracked locations. The same is true for vibratory response as shown in Figure NFII-6. Response of the drywall joint D1 to ground motions is small and barely out of noise level.

Dynamic response time histories of crack response to both blast induced effects and occupant activity are shown in Figure NFII-7. This figure presents dynamic responses for the kitchen-garage door frame interface crack and the corner crack respectively. The ground motion and air overpressure excitation time histories are shown as the upper four time histories for each of the three crack responses. Responses to occupant activity, shown at the bottom, is high for all the cracks. The door being opened and closed is some 20 to 30 feet away from the cracks. Both cracks respond more to the door opening than they do to ground motion with a peak particle velocity of 0.18 ips or air over pressures of 0.007 psi or 130 dB.
Figure NFII-8 compares the maximum crack response magnitudes from environmental effects with those produced by dynamic events. Long-term response is at least an order of magnitude larger than any of the dynamic responses including the uncracked, drywall joint. The garage door crack responds more in-plane (A1) than out-of-plane (A2). The corner crack responds more in the north-south direction than east-west.

This long period of observation also allows the measurement of seasonal crack response to long-term climate and home heating/air-conditioning. Seasonal effects, when combined with effects of frontal and daily changes in the weather, produce long-term response which can be six times larger than the response to the largest blast-induced ground motions.

See Meissner and Dowding (2009) for full report.
(http://www.iti.northwestern.edu/acm/publications.html)
Figure NFII-2 - Instrument locations that enable measurement of (1) structural response to ground motions (2) crack response in-plane, out-of-plane, and in corners (3) uncracked joint response (4) various triggering methods to capture wind response.
Figure NFII-3 - Installed details of crack perpendicular sensors in corner (top), across CMU-door frame interface (middle) and across ceiling drywall joint (bottom); context on left; detail on right.
Figure NFII-4 - Comparison of the variation in indoor temperature and humidity with crack response in the living space. Indoor temperature and humidity became more tightly controlled when an occupant moved into the house on April 1st.
Figure NFII-5 - Comparison of outdoor temperature and humidity with crack response outside the living space.
Figure NFII-6 - (Left) Comparison of four months of climatologically induced responses of the uncracked drywall joint. 30-day central moving average shown with the thick line. Temperature and Humidity are plotted on the bottom (dotted=inside, solid=outside), and joint responses are plotted on the top with common time and response scales for comparison. (Right) Comparison of ground motions (top) with joint responses (bottom) showing unusually low excitation frequency. (1 ips = 25.4 mm/s, 1 µ-in = 0.025 µm)
Figure NFII-7 - (Left) Comparison of perpendicular crack response of the CMU-door frame to a blast event (0.18 ips PPV) with response to opening and closing of a distant front door. (Right) Comparison of Florida perpendicular responses of the corner crack to blast event (0.18 ips PPV) with response to opening and closing of a distant door.
Figure NFII-8 - Comparison of crack and drywall joint response magnitudes. Long term response is at least an order of magnitude greater than any dynamic event. The interface crack responds more in-plane than out-of-plane. The corner crack responds more north-south than east-west. The percentage is the ratio of max ground motion to max frontal response.