Measure the Crack Instead of Construction Vibrations

by Charles H. Dowding, Ph.D., P.E.

Figure 1 - Typical instrumented room with detail of crack and sensor

Construction is omnipresent in modern-day America. It's the sound and vibration of a nation scrambling to keep up with its burgeoning population. In most states, allowable construction-induced ground motions range from 0.5 to 1.0 inches per second (in/sec) and under certain conditions up to 2.0 in/sec.

However, ground motion as low as 0.02 in/sec can be perceived, and repeated motions throughout the day as low as 0.1 in/sec can cause annoyance. Even responsible construction activity produces motions that may startle people.

Sharing close quarters with housing, businesses, and industrial complexes, construction activity often becomes a lightening rod for more complaints than it deserves. Many people incorrectly believe that construction vibration causes damage to their homes or buildings. What these people tend to focus on are cracks like that in Figure 1.

Because many people interpret the response of buildings in their own terms, they tend to believe that if the vibration can be felt, it must be having a negative effect on the structure. The fact is, cosmetic cracking from construction vibrations has not been observed below peak particle velocities of 0.8 in/sec.

Currently, complaints are addressed by measuring peak ground motions outside the structure with a blasting seismograph. These measured peak ground motions are then compared with a standard developed by the federal or state government.

Motions that people truly believe are harmful usually turn out to be below the government standard. These standards, developed by some unknown government officials or researchers, are met with skepticism. Furthermore, it's difficult to convince skeptics that the "silent crackers" - temperature and humidity - produce more cracking than a phenomena that is felt and heard.

MEASURE THE CRACK

All homes are cracked to some extent. Advances in sensor technology and computerized data acquisition now make it possible to address fears of vibration-induced cracking by directly measuring crack response.

Relatively inexpensive systems to monitor both crack response and ground motion have been developed that involve the manual downloading of data on a periodic basis. These systems can be combined with telecommunications for display on the Internet. The public can then access the data, which increases their confidence in the information.

Measuring the crack response directly has several advantages over the current approach of measuring ground motion. First, the response of the cracks that are the most visible to owners are directly involved. Second, ground motion complexities and their indirect relationship to damage are avoided. Third, and most important, crack response to vibratory events can be compared to that produced by long-term factors such as changes in the weather.

A special dual-purpose sensor like that shown in Figure 1 can be placed across a crack to simultaneously measure long-term and vibratory changes in crack width. This direct measurement, termed "crack displacement" is simple to understand and requires no reliance upon empirical guidelines.

HOUSE AND CRACK RESPONSE TO VIBRATIONS

Crack measurement concepts are illustrated by the response of a wood-frame house in central Indiana subjected to repeated blasts from a nearby surfact coal mine. The house was heavily instrumented by the author to assess the effects of environmental changes (temperature, humidity, soil volume change, and frost heave, for example), and to compare them with those produced by blasting and human activity.

The house was purchased from its owner, who had constructed two additions to the original midsection. Thus it was built of materials and was in a condition typical of many older houses. The house was vacant during testing. However, the vibration system was so sensitive it could detect the arrival of the cleaning service.

A similar house has been instrumented on the Northwestern University campus and is linked to the Internet at http://www.iti.northwestern.edu/acm. Accessing this site allows observation of the response of cracks to changes in temperature and humidity, as well as occupant-induced motions.

The time history of response to a blast is shown in Figure 2. By comparing timing of the peaks, it can be seen that the initial higher frequency portion of the ground motion - "Long" (longitudinal), "Tran" (transverse) and "Vert" in figure 2 - produces the greatest velocity response (d1 and d2) at the center of an interior and an exterior wall, while the trailing lower frequency portion produces the largest super-structure response (d3 and d4) at the corner of the second story.

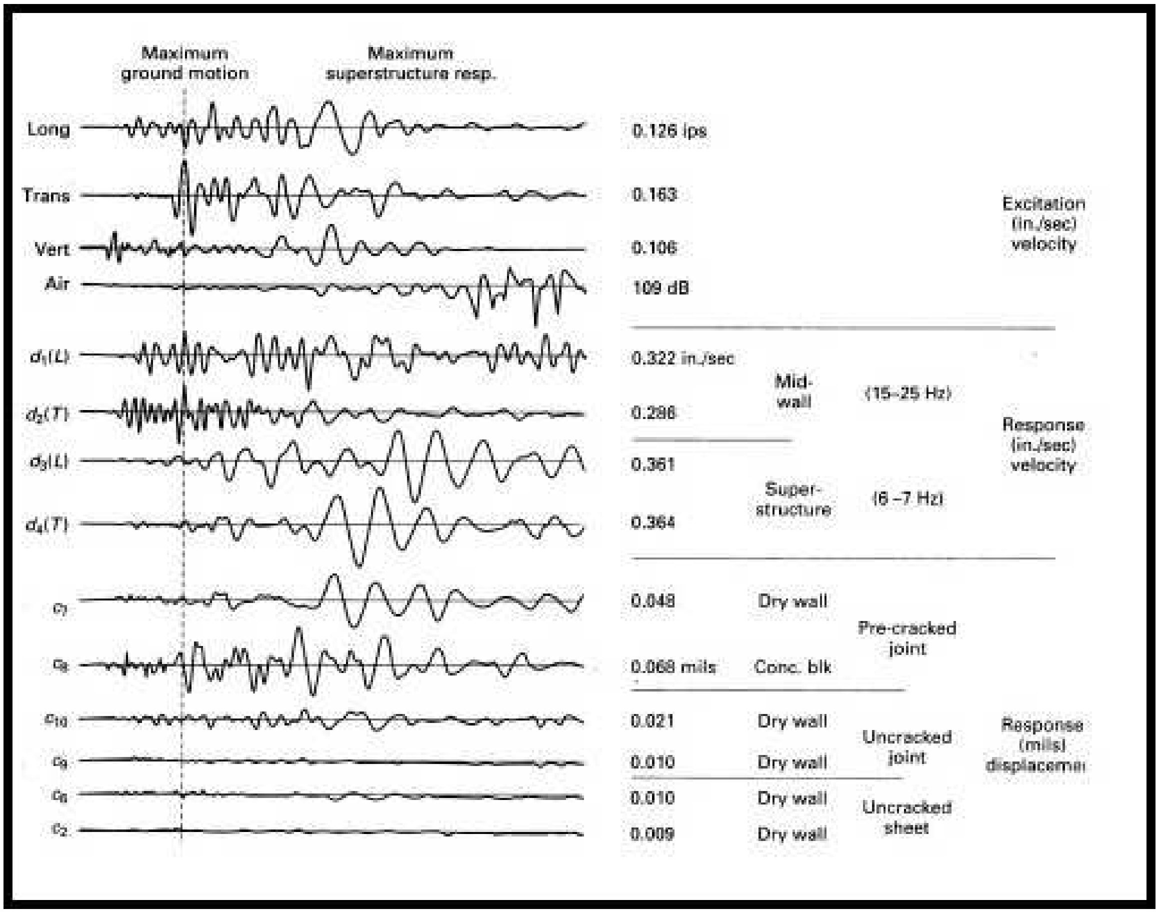

Figure 2 - Time histories of ground motions, as well as house and crack response from a typical blast.

Crack displacements on an exterior wall of the single story portion of the house (c10) are produced by both high and low frequency portions of the motions, whereas those at the corner of an interior doorway immediately below sotry (c7) are larger during the low frequency portion. All sensors were placed on the inside of the house.

Regardless of the crack sensor location, the measurements research demonstrate a very important point about vibration-induced cracking displacement: Crack displacements do not necessarily result in permanent offset. As long as the ground motion is within allowable limits, the ground motion after it passes, excitation dies out and so does the building and crack response. Thus there is no residual or long-term impact because the crack width returns to its pre-blast opening. The same cannot be said for weather and other long-term effects..

WEATHER-INDUCED CRACKING

The same crack width sensors that responded to vibratory excitation were also able to detect response to changes in crack width caused by changes in temperature and humidity. Seasonal and weather front-induced variations in crack displacement can be seen in Figure 3, which compares crack displacements to outside humidity over an eight month period.

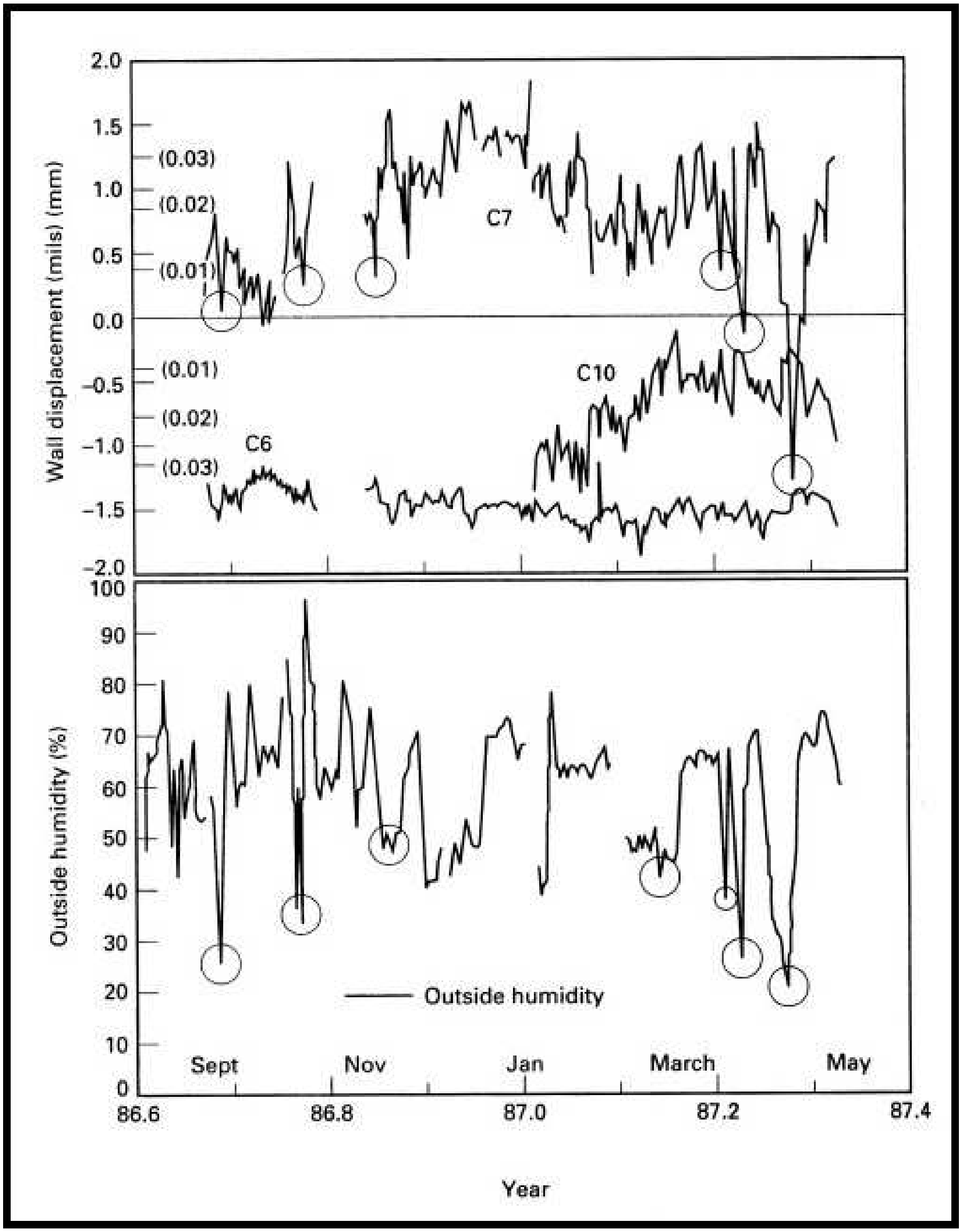

Figure 3 - Comparison of displacement response of cracked tape joint (c7), un-cracked dry wall (c6) and un-cracked tape joint (c10) with changes in outside humidity.

Unusually large changes in humidity are circled in the lower graph of outside humidity for comparison with the corresponding displacement response of wall cracks, which are circled in the upper graph of crack displacement. The weather front-induced crack responses with a duration of about a week are equal and sometimes greater than the seasonal responses that have a length of several months.

Three sensor positions were chosen to demonstrate the effects of differences in drywall detail wall deformation over an eight-month period. Position c6, the least responsive, is located on the middle of a continuous drywall sheet on an interior wall and did not span a crack or a joint between drywall sheets. Sensor c7 spans the most active drywall crack located at a tape joint between drywall sheets on an exterior wall.

WEATHER AND VIBRATION DISPLACEMENTS COMPARED

In Figure 4, environmental and vibration-induced displacements are compared directly for transducer location c7 in units of mils (l/l000th of an inch or 0.025 millimeters). Transducer c7 showed the most response to both environmental and vibration effects as a function of time, and most clearly shows the relative effect of each.

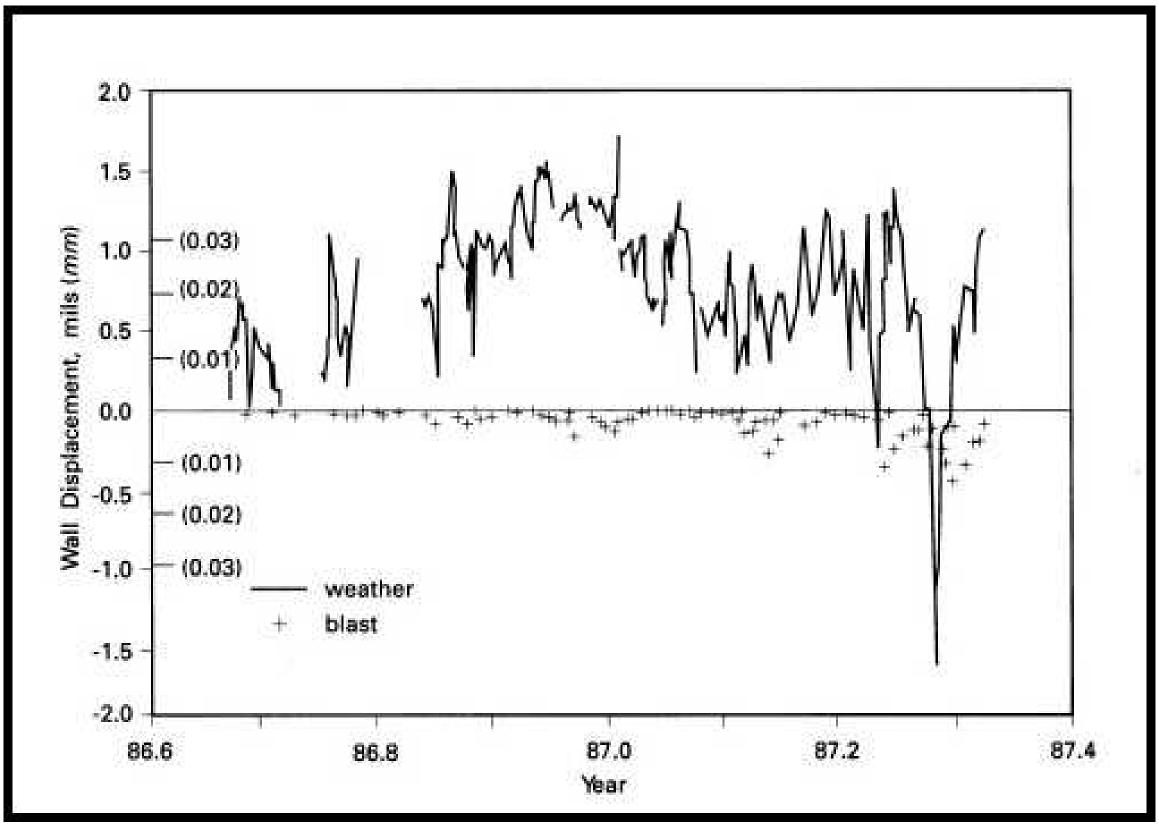

Figure 4 - Comparison of long-term (silent) weather induced crack response to that from blasting.

The weather effects, measured two to three times daily, appear as a continuous function. Blasting events occurred on average less than once per day and appear as individual point events marked by the plus signs. During the eight months of observation, mining advanced toward the test house as reflected by the increase in blast-induced displacement.

The greatest blast-induced vibration during this period was 0.75 in/sec. Despite this significant vibration level, the induced crack displacement was a good deal less than the average change produced by the passage of a significant weather front. The maximum weather induced deformation was some 3.5 times that of the maximum produced by blasting.

Thus, approximately once a week this house is naturally subjected by changes in the weather to deformations that produce crack displacements equal to those produced by ground motions of at least 0.5 in/sec. Every week, season by season, houses deform significantly more than they would from a typical blast.

The difference between environmental and vibration phenomena is that the weather effect occurs slowly and without noise. It is therefore undetectable by the home owners and neighbors. But with new crack displacement techniques, owners can see the effects of weather-induced cracking with their own eyes. They can also see that vibration-induced cracking may not be "all that it's cracked up to be."

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