Instrumental Detection of a Climatologically-Induced Cosmetic Crack in Wall Covering

Charles Dowding, Dept. of Civil & Environmental Engineering, Northwestern University
Justin Lueker, Ebert & Baumann, Washington, DC
Pierre-Alexandre Abeel, Subsea 7, Houston TX

Abstract

When blasting is eliminated as a cause of cosmetic cracking, often someone will ask, “If blasting didn’t cause the crack, then what did?” This paper describes detection by remotely operated instrumentation of the new cosmetic crack that was climatologically-induced. The measurement was obtained as a part of the development of Autonomous Crack Measurement (ACM) instruments to measure micro-inch response of cracks to both long-term, climatological, and dynamic, blast vibration effects. The crack occurred in the wall of a structure that was monitored for over 29 months and as such represents one of the longest periods of ACM observation.

A comparison of weather records, house maintenance, continuous monitoring, and logs of quarry activity show that this crack was most likely the result of cessation of home heating during the onset of winter weather. Measured crack response following the cessation of heating shows that existing cracks widened to an extent roughly 30% larger than at any point in the previous 29-month study period prior to the formation of a new crack through the null gauge. Null sensors were affixed to walls with an existing crack to determine the response of the sensor and wall material, which is normally miniscule.

Introduction

This paper describes the conditions surrounding instrumented detection of a cosmetic crack in a drywall-covered wall. This measurement was obtained as a part of the development of Autonomous Crack Measurement (ACM) instruments to measure the micro-inch response of cracks to both long-term climatological, and dynamic vibratory effects. This particular site was monitored for over 29 months or nearly three years, and as such represents one of the longest such studies.

This article is organized with the following six sections: Test house, Instrumentation, ACM operation, Detection of a new crack, Blasting considerations, and Conclusion. It focuses on the formation and continued monitoring of the null gauge crack most likely caused by cessation of heating. Detailed descriptions of the fully instrumented system and responses of other cracks throughout the house can be found in previously published articles (Meissner 2010, Dowding et al.).

Test house

The instrumented house is a two-story wood-framed structure with a basement foundation. It is located approximately 300 feet (91 m) away from the edge of the blasting zone of Vulcan Material, Co. Sycamore #397 Quarry. The house and its proximity to the quarry are shown in Figure 1.

Figure 1. Instrumented house located just south of the quarry. Response of cracks in south wall (indicated by white arrow) under observation at time of the appearance of new crack. Map data © 2013 Google, USDA Farm Service Agency.

Instrumentation

The ITI research-engineering group installed the ACM system on June 16th and 17th, 2010. Data collection began on July 2nd, and continued without interruptions until February of 2013. The air overpressure transducer and the indoor temperature and humidity gauge were installed on July 21st, 2010. The air overpressure transducer did not begin recording properly until November of 2010.

Structural and crack response is autonomously measured by the combination of sensors listed in Table 1. The crack sensors are described in more detail in the section below. All the other sensors are described in the Installation Report (Meissner, 2010) and crack response reports (Dowding et al. 2011 and 2013). These reports describe the instrumentation system in detail and can be consulted for a more complete description of the dynamic response of the house and cracks.

Table 1. Description of sensors, channel designation and location.

Sensor	Description, Location
Triaxial Geophone	Ground particle velocity, Buried outdoors, southeast corner
Pressure transducer	Air overpressure, Outside north wall
Thermometer and hydrometer	Indoor temperature and humidity, south wall 1^{st} floor
Linear Variable Differential Transformer (LVDT) (Micro-inch displacement)	Shear crack response, South wall, 1^{st} floor
	Null gauge, Uncracked area adjacent to Shear crack
	Addition seam crack response, South wall, 1^{st} floor
	Ceiling crack response, Bedroom ceiling, 2^{nd} floor
Horizontal Wall Geophone with north/south sensitive axis	Superstructure response velocity, Bottom SE corner, 1^{st} floor
	Superstructure response velocity, Top SE corner, 1^{st} floor
	Superstructure response velocity, Top SE corner, 2^{nd} floor
	Wall response velocity, South midwall, 1^{st} floor

Gauges are shown in context in the photograph of the south wall in Figure 2 and in detail in Figure 3. Two LVDTs (rectangular gauges) were placed across a shear and seam crack and a third was placed on the wall as a null to track wall and gauge response. Also shown are string potentiometers (small square gauges) employed in a wireless system (Dowding, 2011) and the midwall velocity transducer.

Figure 3 shows the specific area that cracked with the LVDT and potentiometer in position across the shear crack (upper) and on an uncracked section (lower) to serve as null gauges. At the time of the crack the potentiometer was not in service. The LVDT and potentiometer across the ceiling crack are shown in Figure 4.

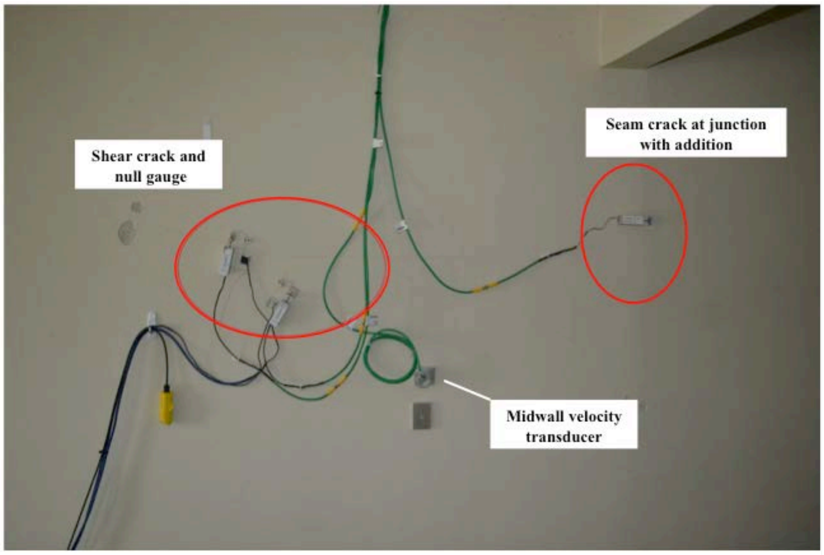

Figure 2. Context of crack observation in south-facing 1st floor wall; shear crack gauge and null left, seam crack gauge on right at junction of addition shown by overhead beam.

Figure 3. Details of the shear crack and crack gauges (LVDT and potentiometer) and null gauge before appearance of the crack.

Figure 4. Details of the ceiling crack and crack gauges (LVDT and potentiometer).

ACM operation

The ACM system is designed to compare crack records to long term, climate effect as well as dynamic effects of external events such as blasting and wind gusts and interval events such as occupant activity.

Both long-term and dynamic data are recorded. These are defined as follows:

- Long-term response is obtained by measuring crack response, temperature and humidity once every hour. Single points of crack response are the average of 1000 samples obtained in one second in order to eliminate the influence of single pulse voltage spikes.
- Dynamic response is obtained by measuring crack response, ground and structural velocity, and air overpressure. These values are recorded at 1000 samples per second for three seconds when triggered during dynamic events, with a 0.5 second pre-trigger.

Crack response is the change in crack width, not total crack width, and is called response in this report. Figure 5 (Siebert, 2000) illustrates this definition. All transducers have been installed so that positive response indicates crack opening and negative indicates crack closing. All measurements are made in micro-inches. The null sensor placed on an adjacent uncracked area was intended to provide a record of any drift or thermal effects on sensor metal or electronics. Prior to the null gauge activity outlined in this report, it was been shown that the null sensor's responses were small relative to those of the cracks (Kosnik, 2008).

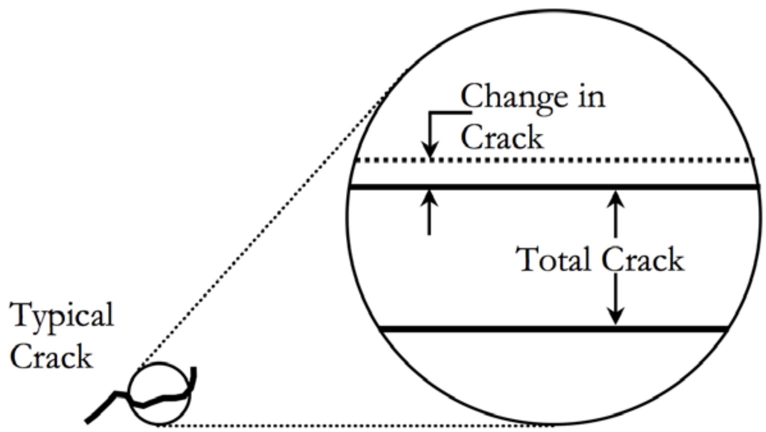

Figure 5. Crack response is change in crack width, not total crack width (Siebert, 2000).

Detection of new crack

After more than two years of no response, a large step was detected by the null gauge between November 19^{th}-20^{th}, 2012. The data that were gathered indicated that it might have spanned a crack, as shown in Figure 6. Proof of the existence of a new crack was found during decommissioning of the equipment at the test site, as shown in Figure 7. This was the first detectable activity occurring in the null gauge since installation more than two years prior.

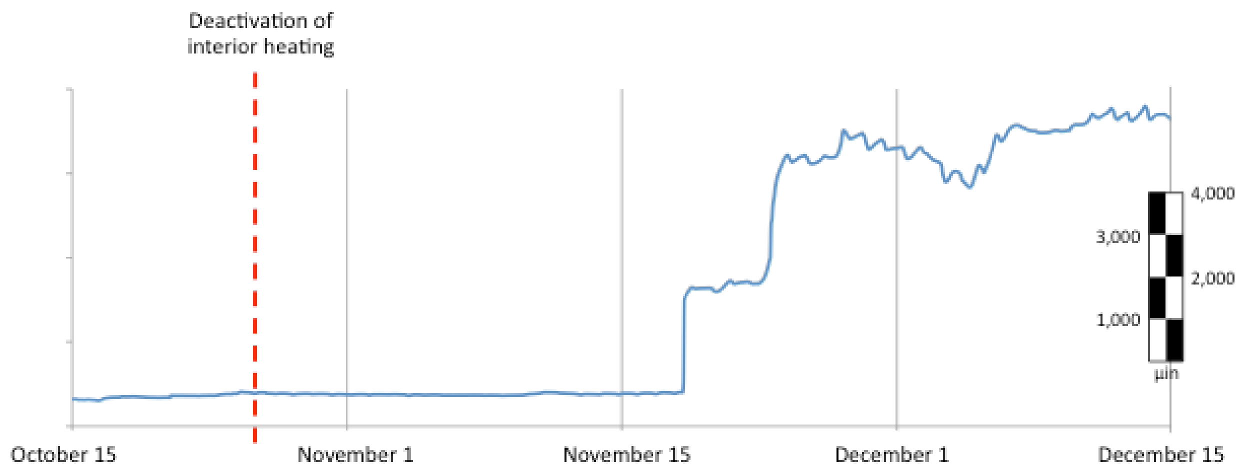

Figure 6. Null gauge response between November 15th-December 15th, 2012. Deactivation of interior heating sometime around October 25th indicated by a dotted line, and subsequent response in null gauge between November 19th-20th is shown in blue.

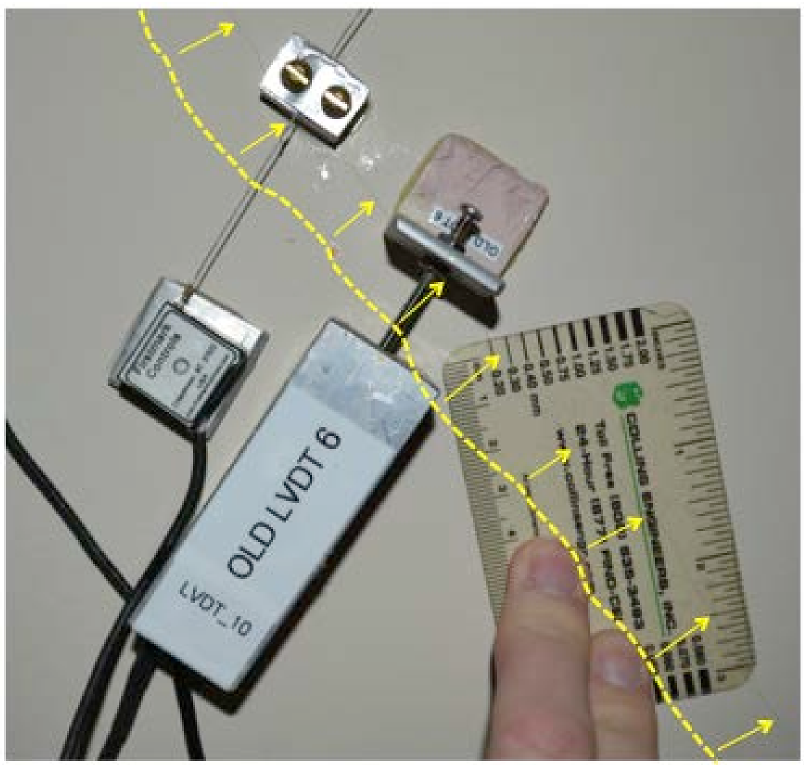

Figure 7: Null gauge with arrows pointing to the visible crack and an offset dotted line indicating the crack contour. The crack gauge shows an approximate crack width of 0.20 mm.

Figure 8 compares the response of the null gauge with long-term response of shear, seam, and ceiling cracks, respectively. Between July 2010-July 2012 there appears to be an annual cycle of crack response magnitude. This cyclic pattern is especially pronounced in the shear crack, which is nearest to the new crack on the instrumented wall and whose time history is documented in Figure 8.

After October of 2012, there is a large aberration from the previous cyclic responses of all three cracks as well as the null gauge. The responses of these three cracks exceed those recorded over the previous two years around the same time that the null gauge detected activity. This can be seen near the intersection of the dotted lines in Figure 8. This exceedance was not small; as shown by comparison with the past annual peaks (indicated by the horizontal line), the exceedance was some 20% to 30% larger, or 4000 μin-6000 μin.

The 29-month study period comprises one of the longest known periods of continuous monitoring of crack response in such a test house. It includes two other large responses during the fall and winter seasons of 2010 and 2011, which was repeated in 2012 when the null gauge crack appeared. This yearly cycle had been seen in two other studies where multiyear responses were observed (Dowding 2008, Meissner and Dowding 2009).

Deactivation of Heating Correlates with Crack Appearance

The interior temperature data in Figure 9 show that sometime in October of 2012, there was a dramatic drop in temperature inside the house. The drop resulted from the deactivation of the heating system in the house to make way for its demolition to allow for the quarry's southerly expansion. The relatively constant temperature observed in the house between January-October 2012 was replaced with temperature that equaled outdoor temperature and matched its daily fluctuations. Not long thereafter, the aforementioned aberration from previous cyclic responses occurred and the sudden response in the null gauge was detected. This timing points to the likely relationship between interior temperature and the formation of the null gauge crack.

As shown in Figure 9, some time passed between the deactivation of interior heating and the crack response across the null gauge. This time lag is consistent with the notion that the interior walls (and accordingly, the pre-existing cracks being tested) must undergo some level of temperature-induced distortion before a new crack can form.

Exterior temperature data in this study was obtained from records at the Dekalb Municipal Airport, roughly 8 miles (13 km) to the south. Data from this airport represents the most detailed record of climate data in the proximity of the test house.

Blasting Considerations

Blasting data from Vulcan Materials show a lack of connection between quarry activity and null gauge response. During the period from July 2010 to September 2012, the quarry generated blasts 36 times. Blasts were initiated at varying distances from the house: between 300 ft and 1,400 ft (90 m – 425 m) away. These distances were provided by Vulcan Materials and evaluated using triangulation between the blasts and surrounding houses. The final blast of 2012 occurred on September 24th, nearly two months prior to the appearance of the new crack.

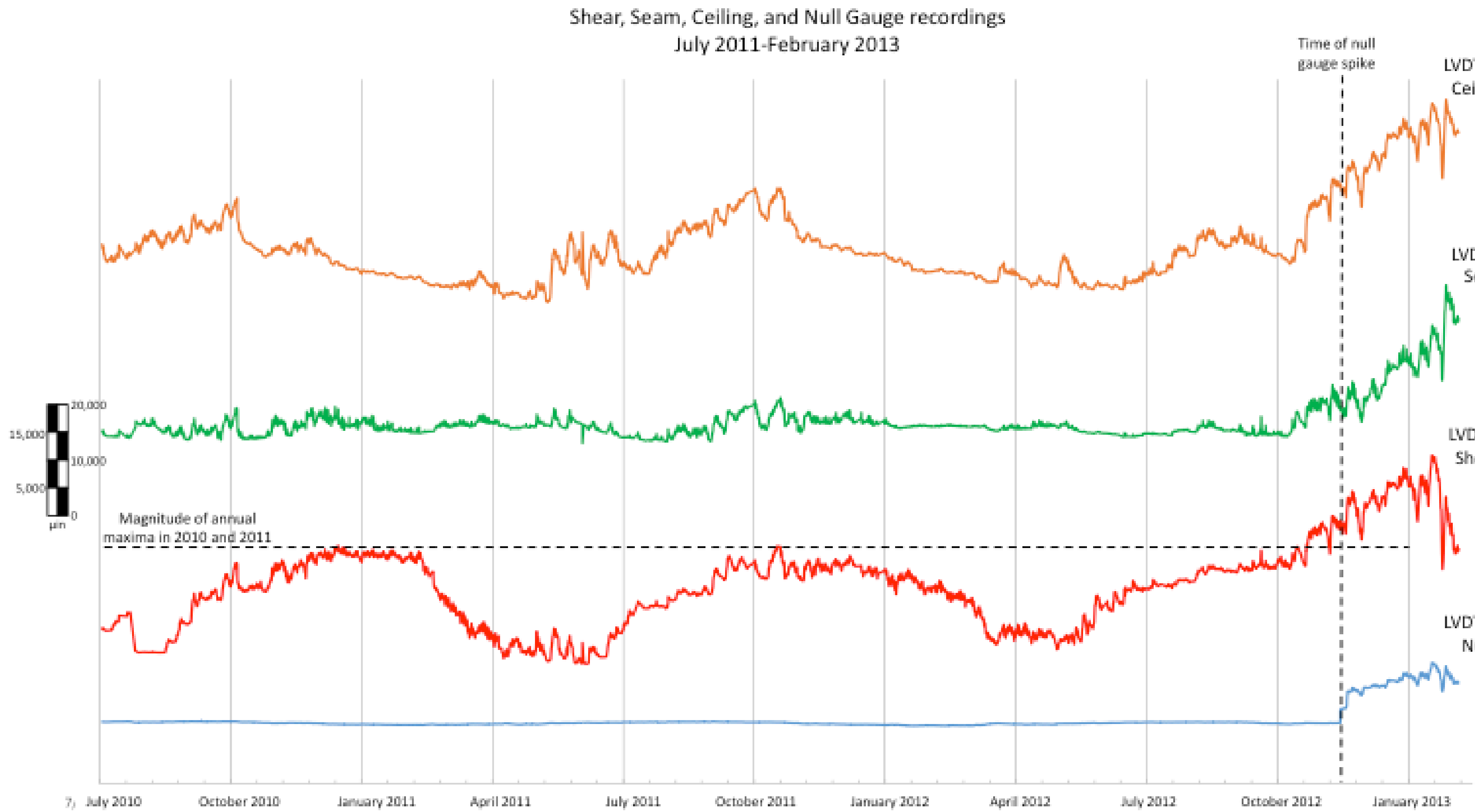

Figure 8. Timing of crack formation through uncracked wall beneath null gauge. Precise instant of null gauge activity is marked by a vertical dotted line. Previous cyclic maxima from 2010 and 2011 is marked by a horizontal dotted line.

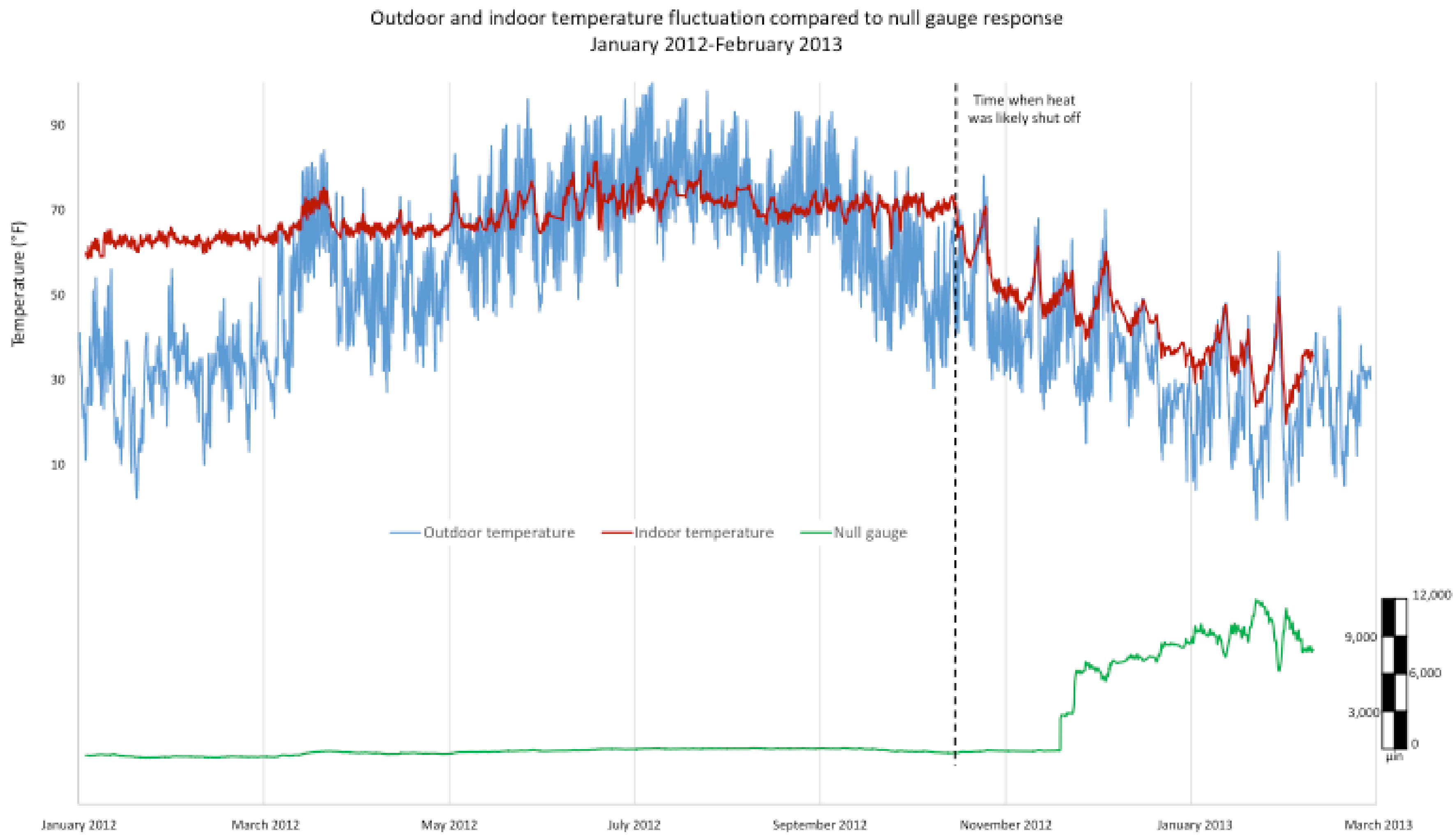

Figure 9. Comparison of outdoor and indoor temperature fluctuation and null gauge response between January 2012-February 2013. The instant of interior heat deactivation is shown with a dotted line. Outdoor temperature data comes from climate records at the Dekalb Municipal Airport, roughly 8 miles (13 km) to the south.

Conclusion

A number of possible causes were analyzed for the crack through the test house's null gauge discussed in this paper. Time histories of both the micrometer crack responses and indoor and outdoor temperature, as well as blasting information, show that it is most likely that the deactivation of interior heating in October of 2012 was the primary cause of increase in shear, seam, and ceiling crack responses. Ultimately, the change in thermal environment led to increased distortion (reflected by the unusual increase in crack response) followed by the appearance of the new crack.

Acknowledgements

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All the above references, except Dowding (2008), can be downloaded at http://iti.northwestern.edu/acm/publications.html