

## APPENDIX TM

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### Trenton, Michigan (2005)

#### Quarry Blasting - Sibley Limestone Quarry

*Aimone-Martin 2005*



**Figure TM-1** - Photographs of the two-story Welch Residence (left) and one story Marian Manor (right)

#### **Background**

The photographs of two structures studied near the Sibley Limestone Quarry are shown in Figure TM-1. They were monitored with the hybrid combination of the ITI ACM system and LARCOR standard vibration monitoring seismograph (AMA et al, 2002). This combination allows recording of vibratory response time histories of both crack and structural response to either ground motions or air over-pressures as well as long-term, climatological crack response. See App. KI for a detailed description of the hybrid ACM-seismograph system used in these studies. Figures in this appendix were copied directly from Aimone-Martin (2005).

The Welch Residence is a wood frame two-story house (with full basement) covered with brick and vinyl siding. A second story bedroom was equipped with the instrumentation as an interior drywall crack in the southwest wall was monitored. Figure TM-2 shows the house and locations of the sensors. The Marian Manor by contrast is a slab on grade one story concrete masonry unit structure with a fire-clay brick façade. The interior was equipped with instrumentation and a crack in the west wall near a window was monitored. Figure TM-3 shows the structure and location of sensors.

Vibratory time histories of the upper (S2) and lower (S1) corner and mid wall (MW) displacement, airblast, and ground motions (GV) perpendicular to the plane containing the cracks for a 7/26 blast at the Welch Residence and a 6/16 blast at Marian Manor are shown in Figures TM-4 and TM-5 respectively. These ground motions produce structural responses, which in turn drive the crack response. Crack responses are greatest when the difference between S1 and S2 is the greatest. This shows that wall strains drive crack response.

Tables TM-1 and TM-2 describes the differential displacements of the upper and lower corners along with calculated wall strains and crack responses at the Welch Residence and Marian Manor respectively.

Figures TM-6 and TM-7 compare the climatological effects on crack response to the response from ground motions. Over an 8 day period at the Welch Residence, the max climatological response is 68 times greater than the blast induced response (20,105  $\mu$ -in to 293  $\mu$ -in peak-to-peak). Over a 24 hour period at the Marian Manor the climate response is 47 times greater than the blast induced response (5,425  $\mu$ -in to 115  $\mu$ -in peak-to-peak).

With maximum PPV's of only 1.73 mm/s (0.068 ips) and 4.19 mm/s (0.165 ips) at the Welch and Marian locations respectively, no ground motion was large enough to develop the crack in either structure. However, it is important to note that even with three times the observed ground motions at Marian Manor, the crack response is only about half as large as at the Welch Residence.

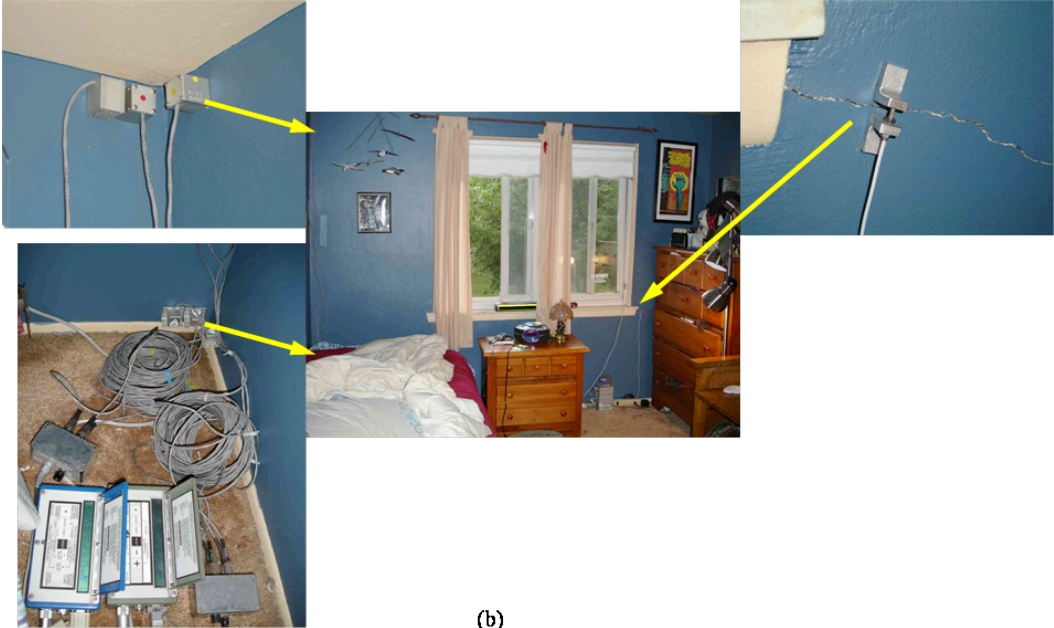
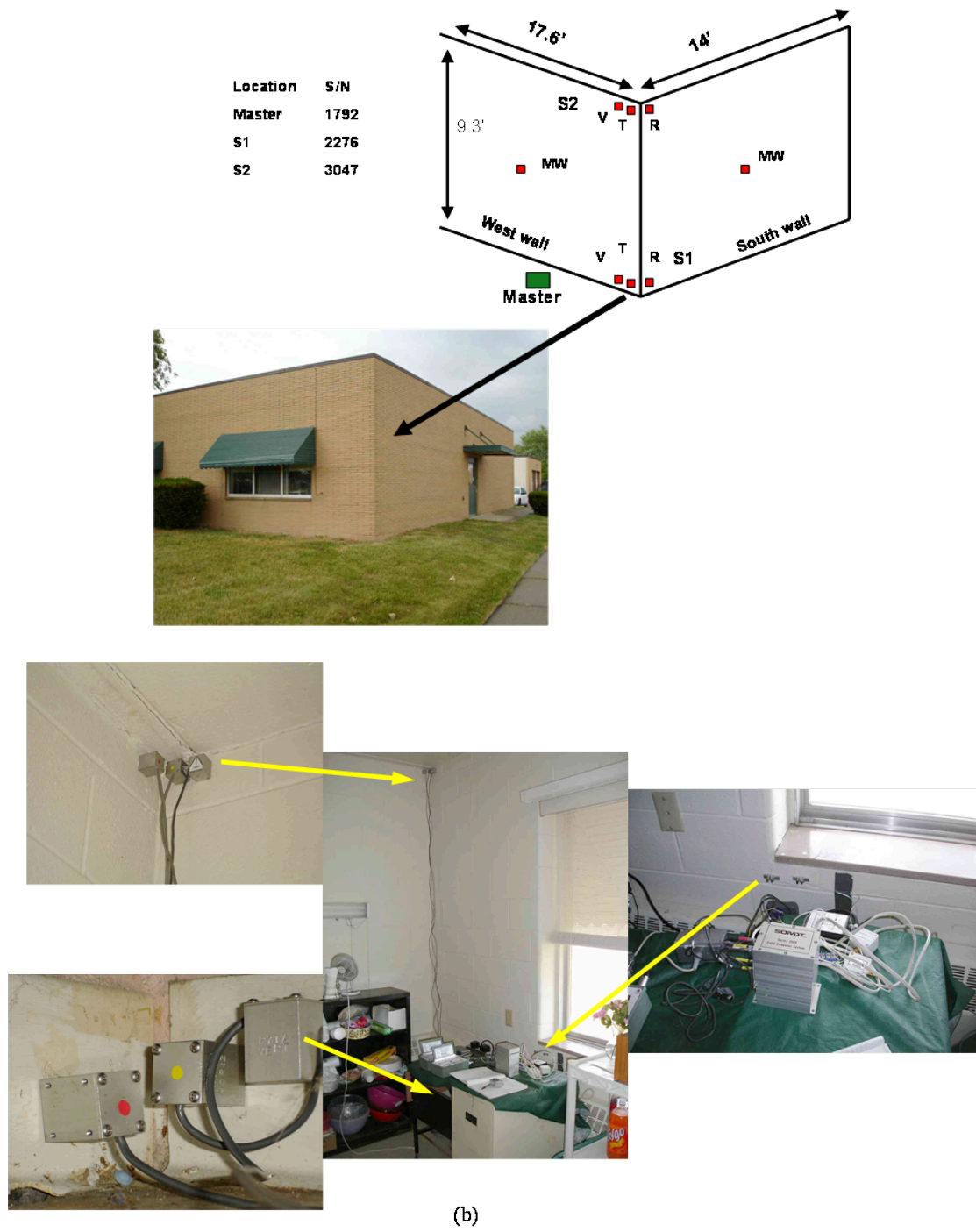


Figure TM-2 - Photograph of Welch Residence along with the locations of the sensors in a second story bedroom

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**Figure TM-2** - Photograph of Marian Manor along with the locations of the sensors in the interior of the brick structure

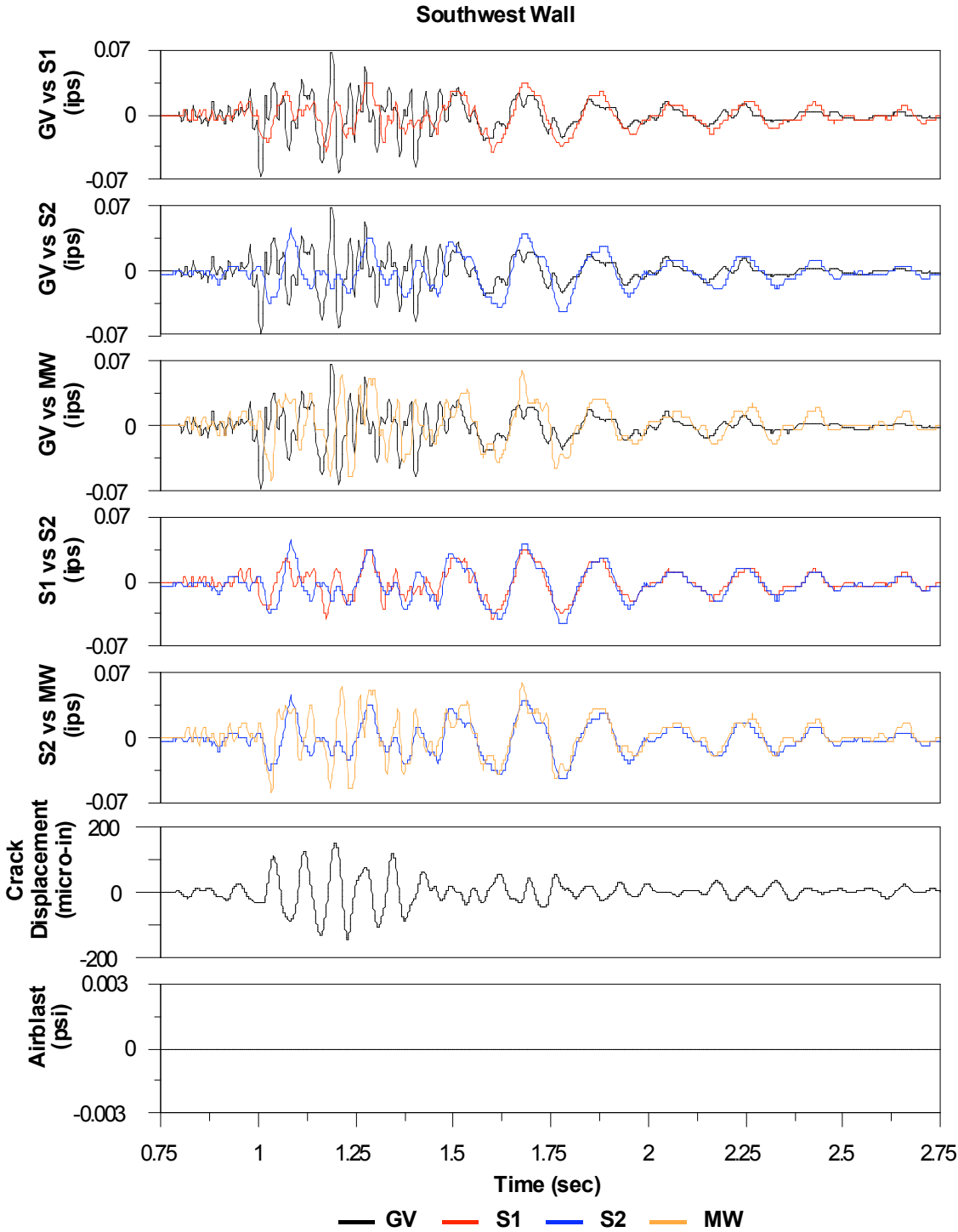
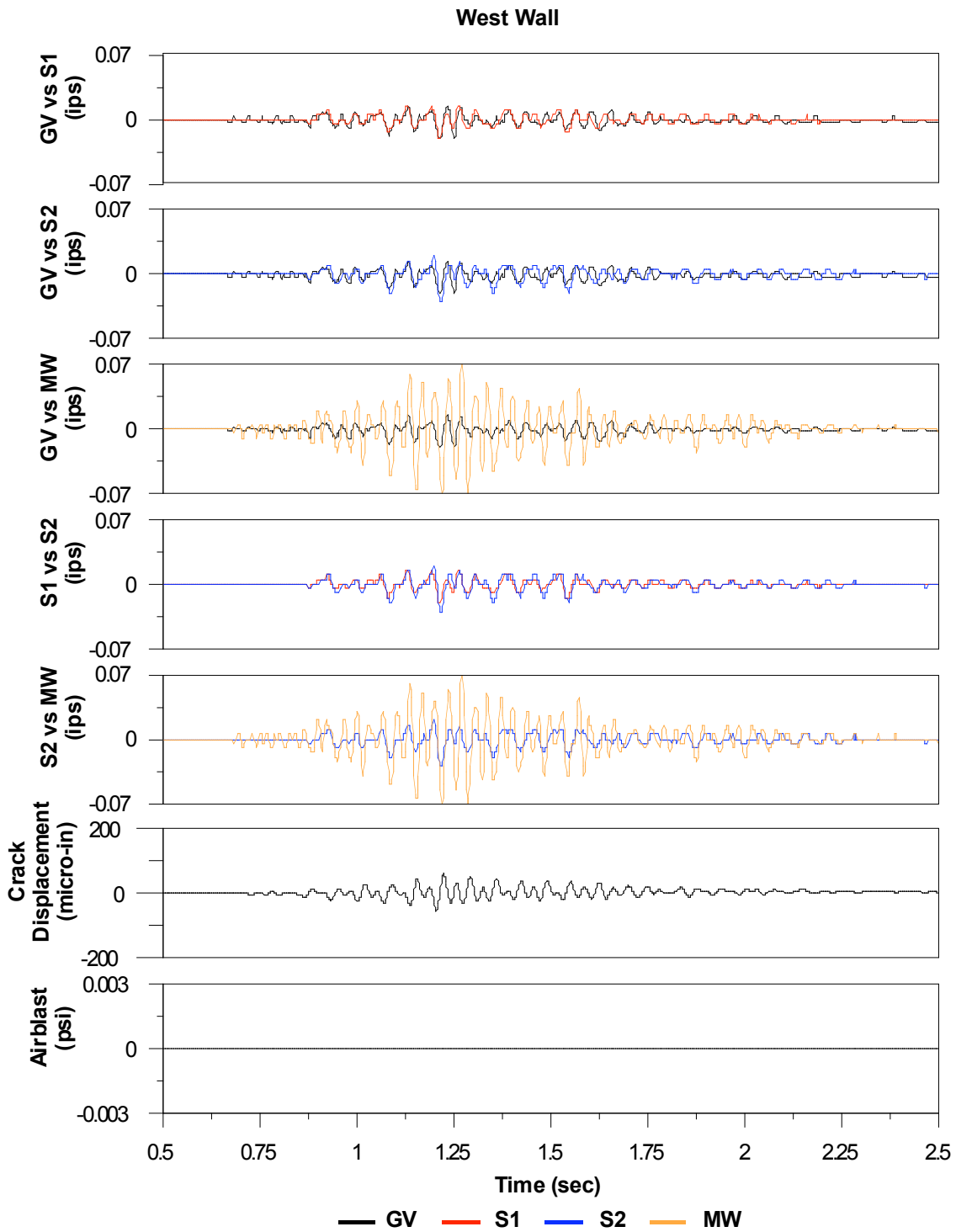


Figure TM-3 - Vibration time histories in the Southwest wall of the Welch Residence during a 7/26/05 blast at 1:12 pm. Transverse GV is compared with S1, S2, MW, and crack displacements.



**Figure TM-4** - Vibration time histories in the West wall of the Marian Manor during a 6/16/05 blast. Transverse GV is compared with S1, S2, MW, and Crack displacements.

Shot Date	Shot Time	Maximum differential wall displacement, S2-S1 (in)		Maximum shear strain (micro-strain)		Maximum in-plane tensile strain (micro-strain)		Maximum bending strain (micro-strain)	Maximum ground velocity (in/sec)		Peak Crack Motion
		SW Wall (T)	SE Wall (R)	SW Wall (T)	SE Wall (R)	SW Wall (T)	SE Wall (R)	SW Wall (T)	Transverse	Radial	(micro-in)
6/16/2005	1:03 PM	nr									
6/21/2005	12:59 PM	nt									
6/21/2005	1:12 PM	0.00044	0.00053	5.89	4.89	2.94	2.37	2.78	0.038	0.038	75.5
6/23/2005	1:00 PM	bad data at S1							0.045	0.048	72.1
6/28/2005	1:00 PM	0.00026	0.00035	3.89	2.89	1.94	1.40	0.93	0.020	0.033	38.7
6/28/2005	1:27 PM	nt									
6/30/2005	12:16 PM	0.00039	0.00068	7.56	4.33	3.78	2.10	1.41	0.035	0.035	47.5
7/5/2005	1:05 PM	0.00041	0.00046	5.11	4.56	2.55	2.20	1.37	0.035	0.065	71.5
7/7/2005	12:59 PM	nt									
7/12/2005	12:59 PM	0.00068	0.00051	5.67	7.56	2.83	3.66	2.57	0.040	0.035	45.7
7/14/2005	1:00 PM	0.00033	0.00058	6.44	3.67	3.22	1.77	1.43	0.038	0.048	nd
7/19/2005	1:02 PM	0.00049	0.00062	6.89	5.44	3.44	2.63	1.74	0.040	0.038	66.8
<b>7/26/2005</b>	<b>1:06 PM</b>	<b>0.00070</b>	<b>0.00112</b>	<b>12.44</b>	<b>7.78</b>	<b>6.22</b>	<b>3.76</b>	<b>2.52</b>	<b>0.055</b>	<b>0.063</b>	<b>115.7</b>
<b>7/26/2005</b>	<b>1:12 PM</b>	<b>0.00096</b>	<b>0.00084</b>	<b>9.33</b>	<b>10.67</b>	<b>4.67</b>	<b>5.16</b>	<b>4.50</b>	<b>0.073</b>	<b>0.065</b>	<b>151.6</b>
7/28/2005	1:13 PM	0.00050	0.00076	5.56	8.44	2.69	4.22	2.44	0.060	0.048	87.7

**Table TM-1** Calculated strains for all blasts at the Welch structure in comparison with ground motion velocity components

Shot Date	Shot Time	Maximum differential wall displacement, S2-S1 (in)		Maximum shear strain (micro-strain)		Maximum in-plane tensile strain (micro-strain)		Maximum bending strain (micro-strain)		Maximum ground velocity (in/sec)		Peak Crack Motion
		West Wall (T)	South Wall (R)	West Wall (T)	South Wall (R)	West Wall (T)	South Wall (R)	West Wall (T)	South Wall (R)	Transverse	Radial	(micro-in)
06/16/05	1:03 PM	0.00024	0.00029	2.60	2.15	1.07	0.85	1.12	0.61	0.020	0.015	64.0
06/21/05	12:59 PM	0.00011	0.00022	1.97	0.99	0.81	0.39	0.45	0.47	0.010	0.008	
06/21/05	1:12 PM	0.00020	0.00031	2.78	1.79	1.15	0.71	0.67	0.96	0.020	0.013	
06/23/05	1:00 PM	0.00048	0.00029	2.60	4.30	1.07	1.70	0.93	0.89	0.030	0.013	
06/28/05	1:00 PM	0.00038	0.00048	4.30	3.41	1.78	1.34	1.34	1.11	0.043	0.035	
06/28/05	1:27 PM	0.00024	0.00030	2.69	2.15	1.11	0.85	0.73	0.81	0.018	0.010	
06/30/05	12:16 PM	0.00026	0.00029	2.60	2.33	1.07	0.92	0.60	0.72	0.020	0.010	
07/05/05	1:05 PM	0.00042	0.00041	3.67	3.76	1.52	1.49	1.08	1.10	0.043	0.065	
07/07/05	12:59 PM	0.00025	0.00029	2.60	2.24	1.07	0.88	0.79	0.83	0.015	0.013	
07/12/05	12:59 PM	0.00027	0.00023	2.06	2.42	0.85	0.96	0.60	0.76	0.020	0.018	
07/14/05	1:00 PM	0.00027	0.00034	3.05	2.42	1.26	0.96	1.05	1.05	0.040	0.043	
07/19/05	1:02 PM	0.00028	0.00038	3.41	2.51	1.41	0.99	0.70	0.92	nd	nd	
07/26/05	1:06 PM	0.00035	0.00067	6.00	3.14	2.48	1.24	1.12	0.89	0.028	0.025	
07/26/05	1:12 PM	0.00027	0.00052	4.66	2.42	1.92	0.96	1.11	0.96	nd	nd	
07/28/05	1:13 PM	0.00016	0.00041	3.67	1.43	1.52	0.57	0.64	0.65	nd	nd	

**Table TM-2** Calculated strains for all blasts at the Marian Manor in comparison with ground motion

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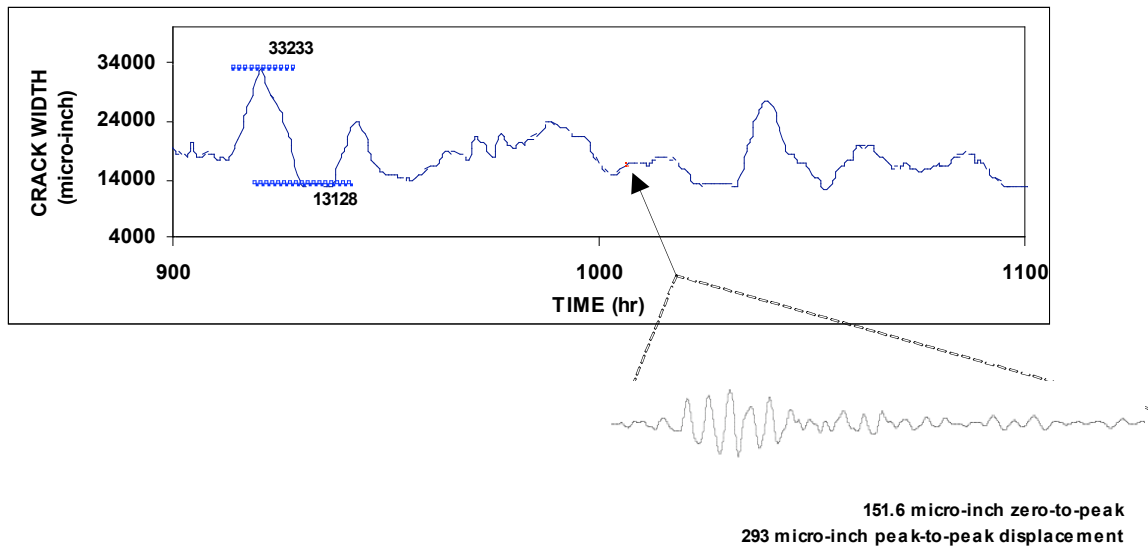


Figure TM-5 - Crack Width over a 200 hour period comparing climatological response to blast induced response (7/26) at the Welch Residence

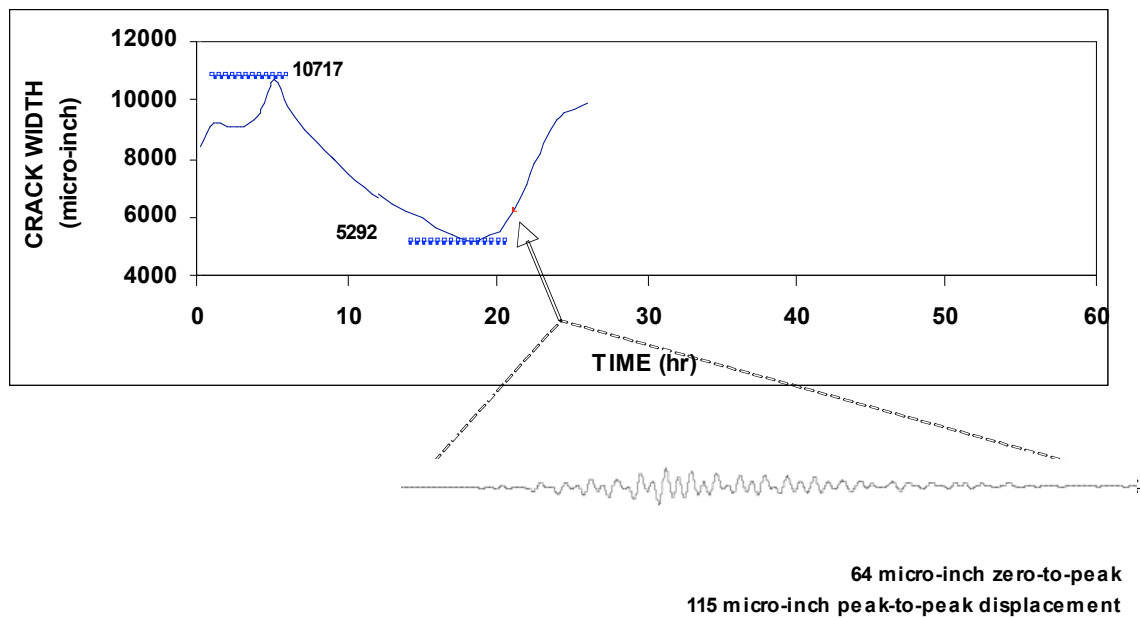


Figure TM-5 - Crack Width over a 24 hour period comparing climatological response to blast induced response (6/16) at Marian Manor