EXECUTIVE SUMMARY

Blasting Attenuation Study
Structure Response Study

Crystal Ridge, MacDonald Ranch and MacDonald Highlands

For the

City of Henderson
240 Water St.
Henderson, Nevada

Prepared by

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President

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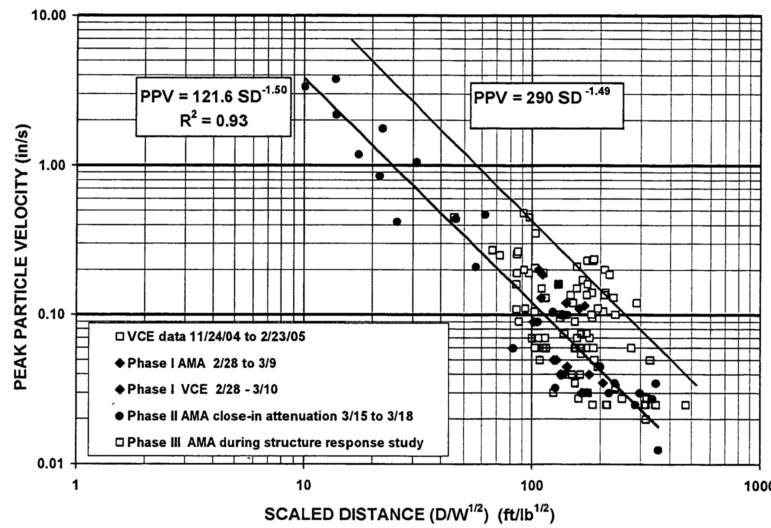
BLASTING ATTENUATION STUDY

A blasting attenuation study was initiated by Aimone-Martin Associates, LLC (AMA) on 2/25/05 to record and evaluate vibration and airblast measurements at locations near current blasting south of West Horizon Ridge Parkway within the neighborhoods of Crystal Ridge, MacDonald Ranch, and MacDonald Highlands. The purpose of this study was to

- evaluate seismograph measurements and data from blasting operators and vibration consultants, VCE, of Las Vegas, Nevada,
- validate measurements recorded by VCE,
- evaluate geological influences that may be contributing to unusual ground vibrations in various directions from blasting operations, and
- evaluate blasting methodology as it may be influencing unpredictable or unusual ground vibrations or airblast.



The best-fit equation (50-percentile) for data recorded during this study was

$$PPV = 121.6SD^{-1.50}$$

with a correlation, R^2, of 0.93. This fit is very close to the fit obtained by Siskind, et al. (1980) during U.S. Bureau of Mines structure response research at coal mines. The 100% confidence line for all data, including data recorded during the Structure Response Study, was

$$PPV = 290SD^{-1.49}$$

Conclusions drawn from this study are as follows:

- Blasting and vibration monitoring and control methods currently employed are state-of-art and represent best practices available in the rock blasting industry.

- Historical vibration records from VCE (prior to 2/25/05, or the commencement of these studies) showed vibration levels slightly higher than those recorded by both VCE and AMA from 2/25/05 to 4/14/05, given a constant distance and explosive charge weight. However all historical data for ground motions were within regulatory limits. This may indicate that more control on blasting was exercised since that inceptions of scientific studies and elevated oversight by the City.

- Post-blast record keeping of blasting and vibration information was lacking in key information upon the commencement of this study and greatly improved over the following 3 months. As a result, blasters were more aware of off-site impacts and responded with improved control measures.

- There are measurable yet minor influences of geology and terrain conditions that appear to enhance ground vibrations in directions that align with the surface ridge lines from the blast sites. The attenuation or decrease in vibration amplitudes with distance in different directions is not statistically significant and does not warrant special regulatory consideration.

STRUTCURE RESPONSE STUDY

The response of two residential structures, one in Sun City MacDonald Ranch and one in MacDonald Highlands, to blasting vibrations was conducted from 3/15/05 to 4/15/05. Structures were instrumented with single-axis velocity geophones to measure whole structure and mid-wall vibratory motions during blasting events. Displacement-type gages were used to measure movement of a pre-existing stucco exterior wall crack during blasting, construction, and wind events. A single tri-axial geophone and air pressure sensor were employed exterior to the dwellings to record ground motions and airblast. Data analyses for blast-induced and other motions were conducted to:

- compare vibration time histories in terms of velocity and calculated displacements within structures relative to ground excitations and air overpressures,
- evaluate response frequencies to determine natural frequencies and damping characteristics,
- determine structure response amplification of ground motions,
- compute differential displacements at corner motions to estimate global shear and in-plane tension wall strains,
- compute bending strains in walls, and
- compare crack movements subjected to blasting, variations in temperature and humidity and wind gusts.

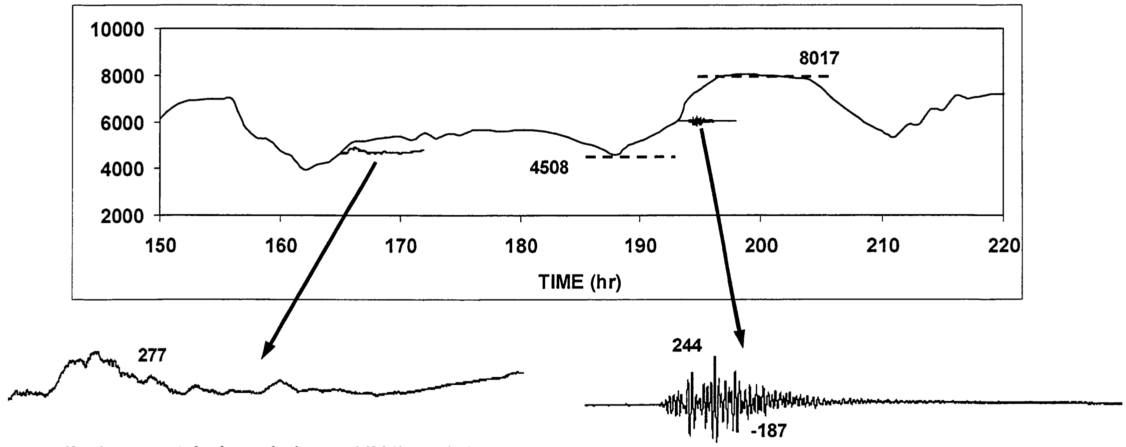
Blasting over the time period of this study did not provide sufficient energy in the ground and into the structures to compute structure damping, natural frequency, and amplification except in the case of the blast on 3/23/05 at 2:47 pm for the structure on Bighorn. The computed 9 Hz natural frequency and damping of 5.4% are within the typical range for residential structures. Structure amplifications of blast excitations were 1.23 and 1.2 for southwest and southeast wall motions and below the average of 2 for typical residential structures.

The blast on 3/23/05 generated maximum in-plane tensile and mid-wall bending strains of 27.8 and 9.4 micro-strains, respectively, in the southwest wall at the dwelling on Bighorn. For the dwelling on High Mesa, the maximum calculated in-plane tensile and mid-wall bending strains were 5.78 and 4.33 micro-strains, respectively, in the northeast wall during the blast on 4/13/05. These computed strains were far below the range of tensile failure strains in gypsum core of interior drywall (300 to 500 micro-strains) and modern stuccos, reinforced with polymeric fiber (exceeding 1,000 micro-strains). At low levels of blasting recorded throughout this study, the induced strains never exceeded the elastic limit of the wall materials and no permanent deformation could have occurred. Hence, cracking both in interior drywalls and exterior stucco is not caused by blasting activities at the excitation levels recorded during this project.

Peak blast-induced dynamic crack displacements ranged from 45.6 to 243.5 micro-inch and 42.6 to 113.6 micro-inch for the structures on Bighorn and High Mesa, respectively. The largest overall weather-induced changes in crack width over the project duration were 8212 and 5403 micro-inch for the structures at High Mesa and Bighorn, respectively.

Daily weather-induced changes in crack width over a 4-day period are compared below with dynamic crack motions for the most significant blast on 3/23/05 (right, for 0.45 in/sec peak ground motion) and high wind gusts (left, for 34 mph winds) for the structure on Bighorn. The maximum daily change of 3509 micro-inch exceeds the largest change in zero-to-peak crack width during blasting (244 micro-inch) while the wind gust zero-to-peak opening (277 micro-inch) was greater than that for the largest blast.

It is therefore concluded that large weather-induced changes in crack width is the greatest contributing factor to crack extension and widening over time. The influence of wind pressures against walls during a typical storm produced crack width changes greater than those produced by blasting when ground vibrations were near the 0.5 in/sec regulatory limit. Hence, the influence of blasting vibrations on crack width changes is negligible compared with the influence of climate and less than the influence of wind gusts. It is highly unlikely that blasting is the source of structure cracking.



Crack displacement during wind gust 3/23/05 at 2:15 am

Crack displacement during blast 3/23/05 at 2:47 pm

Conclusions drawn from this study are as follows:

- There is a 100% probability that blasting at the current regulatory limit does *not* contribute to cracking in structures.
- Structure response data clearly demonstrated that large variations in ambient temperature and humidity produce wall strains up to 72 times greater than those created by blasting at the current regulatory limit of 0.5 in/sec peak ground velocity.
- Structures motions and wall strains produced by wind gusts on the order of 31 to 34 miles per hour were 10% greater than those produced from blasting at the current regulatory limit.
- Ground vibrations from construction activities near structures, ranging from 0.03 to 0.07 in/sec., and resulting wall strains were on the same order as those produced by blasting.
- Airblast or air-born pressures from blasting were negligible and the effects were not detected in structure response motions.

AUTHOR BIOGRAPHY

Dr. Aimone-Martin is President of Aimone-Martin Associates, LLC and a Professor Mining and Civil Engineering at New Mexico Institute of Mining and Technology. She has degrees in geological engineering (with emphasis in geophysics and mining), civil engineering, and mining engineering. Since 1971, she has worked in the mining and construction industries and with geotechnical consulting firms in both the U.S. and Canada, and with Sandia and Los Alamos National Laboratories as a research affiliate. Special projects with national laboratories have included research on electrohydraulic fracture, design of underground nuclear repositories, and solar-powered solution mining concepts for potash extraction. Dr. Aimone-Martin helped to fund for the development of the Center of Explosives Technology and Research at New Mexico Tech with a $5M grant and was Chair of the Mining, Geological, and Environmental Engineering Department for 9 years.

She currently serves as an advisor to Homeland Security and on several national committees and boards including the National Institute of Occupational Health under NIH and the New Mexico Mining Association Board of Directors. She has recently held important U.S. Presidential appointments to the Academy of Sciences of the National Research Council. Dr. Aimone-Martin served 13 years as a Director on the International Society of Explosives Engineering Board (ISEE) and continues to participate on Committees including Seismograph Standards Committee, Public Relations, and Education.

Dr. Aimone-Martin is an international invited speaker, author of over 90 publications, and has received over $ 500,000 in research grants while at New Mexico Tech.

Dr. Aimone-Martin's expertise is in the areas of explosives engineering, rock blasting, structure response to blasting, instrumentation for vibration control and structure response, geotechnical engineering, soil and rock mechanics, foundation design and analysis, risk assessments, regulatory compliance, and public relations. She serves as a consultant to construction, coal, quarrying, and hard rock mining companies in the areas of blast design, vibration monitoring and control, structure response, fragmentation, backbreak control, instrumentation, blasting impact plans, and public relations. Dr. Aimone-Martin has further worked for municipalities in the development of blasting standards and regulations to protect off-site structures and for federal agencies to validate federal safe blasting standards limiting vibration and airblast for general blasting applications throughout the U.S.