

# Structure Response to Seismic Surveys Using Vibroseis and Explosives Methods

Aspect Energy  
Jennings, LA

Residential structure response and ground motion attenuation studies were conducted during seismic exploration surveys in Jennings, LA. The dynamic responses of a residential structure was measured to calculate amplification factors and the maximum induced whole structure and mid-wall strains generated during seismic shooting using 5.5 lbs of high-energy explosives and the deployment of a Vibroseis truck shown in Figure 1. In addition, a close-in attenuation study was conducted to determine the propagation of surface ground motions during the operation of the Vibroseis truck.



Fig. 1 Veritas Vibroseis truck

The purpose of these studies was to determine the characteristics of measured and calculated structure responses and compare the vibration intensities with those that are known to cause cracking in the structures.

## Close-in Vibroseis Attenuation Study

Close-in attenuation of ground motions was performed for three sweep energy intensities (2, 3, and 4 with 2 being the highest energy coupled into the ground surface at the truck base plate) typically used in urban environments during exploration for oil and gas. No information regarding the actual energy input into the ground was available.

The truck weighed 55,116 lbs of which only 70% is typically used during surveys in urban environments. Vibration cycles or sweeps were conducted over a 12-second time period and over the range of frequencies typically used in seismic exploration.

Seismographs were placed at distances of 1.5, 4, 8, and 12 ft. from the edge of a single truck base plate in a linear array. Geophones were buried 4 to 6 inches in the ground with the radial component directed toward the vibrating source. The tests were conducted within soft,

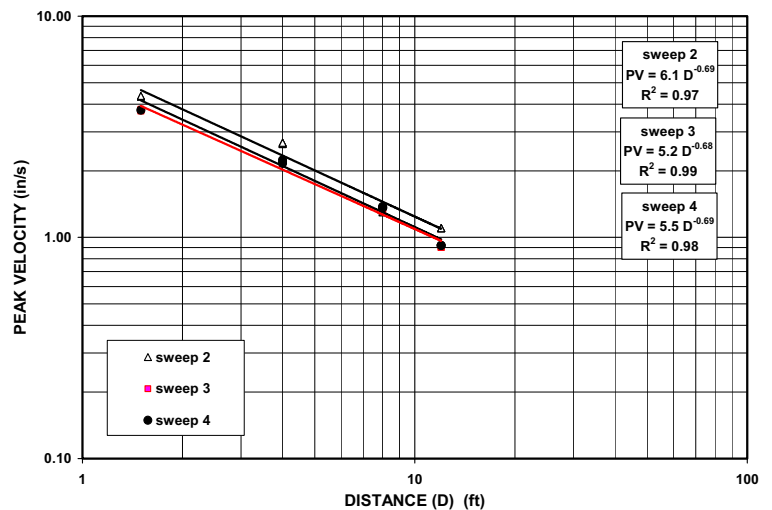


Fig. 2 Attenuation plot, distance to the base plate versus ground motion

saturated clays typical of the near-surface environment of southern Louisiana.

Figure 2 shows the close-in attenuation relationships for the three sweeps. In all cases the maximum velocity component in the ground was the vertical component consistent with the source motion. The Fast Fourier Transform (FFT) predominant frequencies for the three intensities were 45.5 Hz for sweeps 3 and 4 and 20.7 Hz for sweep 2 containing the highest energy. The attenuation characteristics shown in Figure 2 are given in terms of the best-fit power curve equation with a y-intercept indicating energy of the sweep and attenuation slope (negative power of distance) corresponding to the site geology.

Sweep 2, providing the lowest predominant frequency, generated only slightly higher amplitudes of ground motion over the range of distances as expected (y-intercept of 6.1 ips compared with 5.2 and 5.5 for sweeps 3 and 4). In all cases, the saturated clay generated a consistent attenuation or decay parameter of -0.69.

## Structure Response to Vibroseis Vibrations



Fig. 3 Pier and beam, wood-frame structure

Structure response at a wood-frame, single-story, pier and beam residential structure, shown in Figure 3, was measured for a Vibroseis truck stand-off distance of 90 ft from the residence using sweep intensities 2, 3, and 4 used in urban environments.

Sweep level 2 was selected for analysis as this level provided the maximum energy input into the ground used for seismic survey work.

Figure 4 shows a typical vertical component time-history generated during a level 2 sweep through all frequency components at a 90-ft. stand-off distance. The highest ground vibration recorded for all tests was 0.118 in/sec.

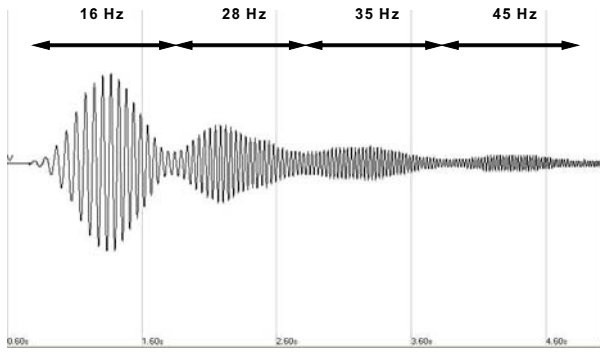


Fig. 4 Vertical ground motion time-history for sweep 2 at a 90-foot stand-off distance showing various frequency components over a 5-sec. window

Four distinct frequencies were present over the 5-sec. window of energy. The four distinct frequencies recorded, each lasting approximately 1 second each, were 16, 28, 35 and 45 Hz. It is noted that each of these frequencies are well above the natural frequencies of 5.0 calculated for the instrumented structure.

Strains were computed from structure motions. Figure 5 show velocity time-histories used to compute strain in walls. The maximum in-plane tensile strain for the interior walls of the structure was 14.68 micro-strains and maximum bending strain was 5.02 micro-strains. The factor of safety against cracking in the interior drywall is 20.4 for interior drywall. The dynamic tensile failure strain for gypsum core of drywall is 300 to 500 micro-strains.

The first row of Figure 5 shows a comparison of ground motion (GV) and lower structure (S1) response for the horizontal radial (left) and vertical components (right). Since the vibratory source isolated ground motions in the vertical direction, there were little or no horizontal motions. However, the structure responded with significant horizontal motions because the house, resting on piers, was not well-coupled to the ground and was able to laterally move with the vertical energy. As such, ground motions were amplified in the lower corner of the structure (S1), shown in the first row. In the second row is a comparison of ground (GV) and upper structure (S2) motions showing that S2 moved with the ground motions resulting in little amplification. Comparing the lower and upper corners (S1 and S2) in the third row indicates higher motions in the upper structure (S2) with the greatest vertical amplification over the 16 Hz portion of the sweep. Rows four and five present a comparison of mid-wall (MW) motions with ground and upper structure motions (S2). Clearly, in the absence of air-borne energy, mid-walls respond with, and are less in amplitude than, upper structure motions.

### Structure Response to Buried Seismic

Single-point shots were conducted using 2.5 lb and 5.5 lb cast boosters comprising Pentolite (50% TNT and 50% PETN). Explosive charges were buried 80 ft. deep at distances from the structures ranging from 417 ft to 996 ft. The highest recorded peak ground velocity was 0.155 in/sec.

Structure motions to shot generating the greatest peak ground velocity is given in Figure 6. The vertical ground motion (GV) and upper and lower structure motions (S2 and

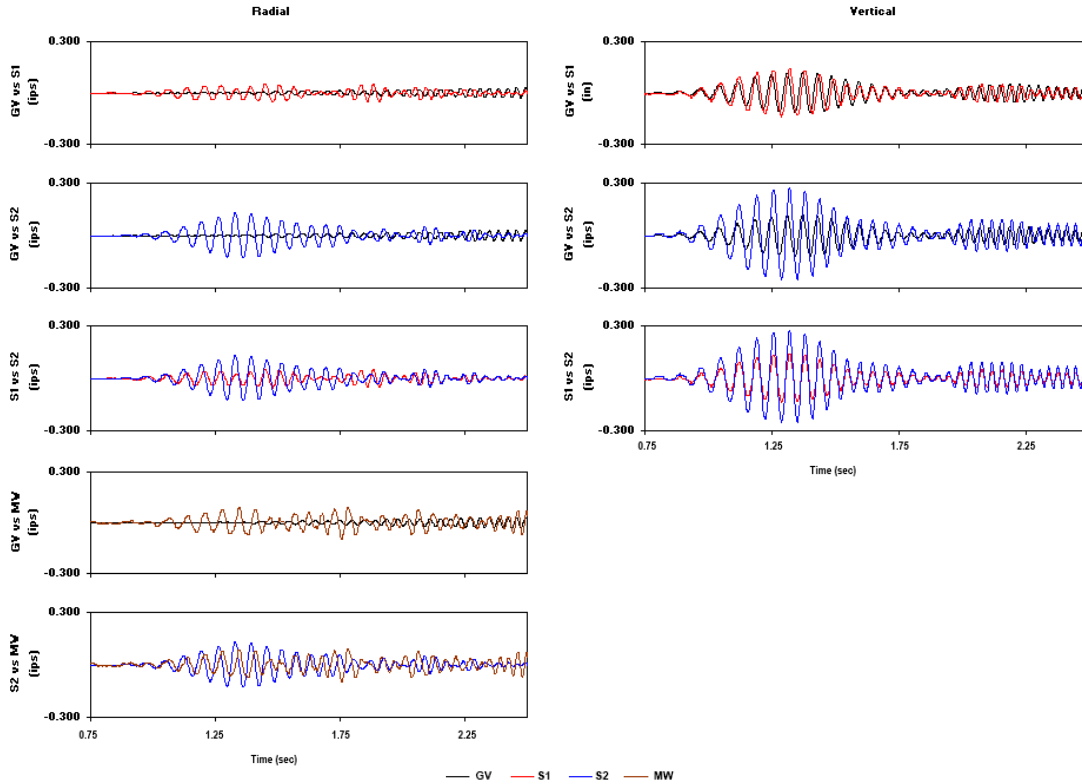


Fig. 5 Velocity time histories comparison plots.

S1) show good agreement with expected upper structure amplification. The horizontal (radial) components of the lower structure (S1) and ground motion (GV) of the first row show initial correspondence until the lower corner develops large amplitude low frequency motions resulting from poor foundation coupling. The second row horizontal motion agreement of the upper structure (S2) with the ground motions (GV) may result from the relatively stiff coupling of the roof to the upper structure effective. The net effect is a random, lower structure motion independent of the ground and upper structure. This is clearly noted in the third row comparing S1 with S2. Initially, the two corners move in unison until 1.6 sec. when the lower corner moves more erratically and independent of the ground due to the poor coupling. Mid-wall (MW) motions shown in the fourth and fifth rows follow the high initial frequencies of GV and later in time track with the lower frequencies of the upper structure response.

Strains computed from structure response data indicated the explosive-induced in-plane tensile strains in the longest wall are similar to those produced by the vibroseis energy. Seismic explosives generated maximum in-plane tensile and mid-wall strains of 20.54 and 12.10 micro-strains while for the Vibroseis the maximum strains were 14.68 and 5.02 micro-strains, respectively. The factor of safety against cracking in the interior drywall for the strains computed for seismic shooting is 14.6 for interior drywall.

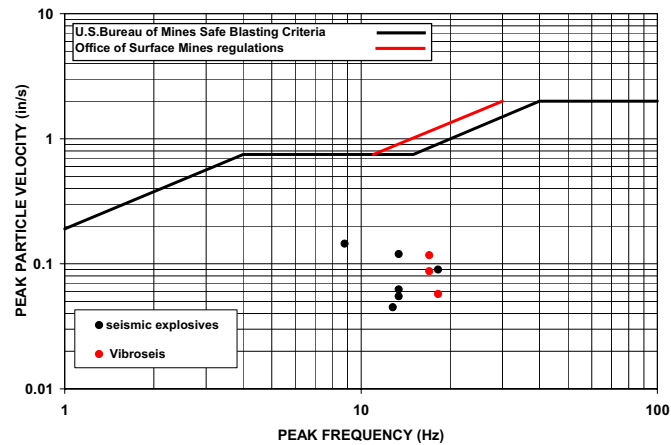


Fig. 7 Peak particle velocity versus peak frequency for seismic shooting and vibroseis (vertical motion only)

### Comparison of Ground Vibration from Different Energy Sources

Figure 7 shows peak particle velocity (PPV) plotted against peak frequency for both energy sources. The predominant Vibroseis frequency is 17.4 Hz while the average frequency from the explosives is 13.6 Hz. In both cases the amplification of the upper structure relative to GV is 2.4.

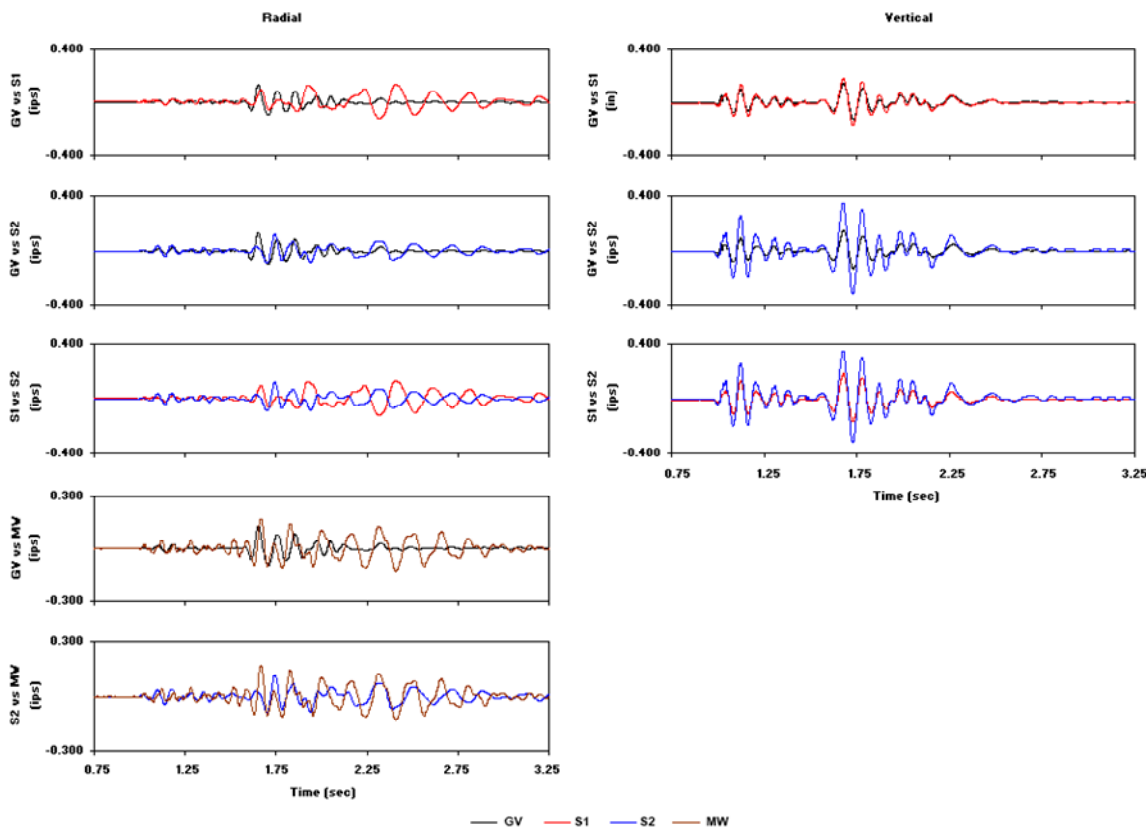


Fig. 6 Velocity time history comparison plots for seismic shooting, 5.5 lbs explosives.