

VERTICAL GROUND MOTIONS  
FOR THE  
DIABLO CANYON  
LONG TERM SEISMIC PROGRAM

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## VERTICAL GROUND MOTIONS FOR THE DIABLO CANYON LONG TERM SEISMIC PROGRAM

The Long Term Seismic Program's vertical response spectra presented in the Final Report (PG&E, 1988) were based on the ratio of vertical to horizontal spectral values obtained directly from a data set of strong-motion recordings of large-magnitude, close-in earthquakes, as described in our Response to Question 17c (January 1989). In 1989 and 1990, during the NRC review of the Long Term Seismic Program Final Report (PG&E, 1988), NRC consultant Dr. Kenneth W. Campbell and PG&E conducted independent vertical ground motion analyses for the Diablo Canyon site based on regression analyses of the vertical component of ground motion. Regression analysis had not previously been applied to spectral ordinates to compute vertical ground motions.

Both PG&E's regression results and Campbell's regression results have changed significantly during the past nine months, with continual refinements in the analysis methods. Although the regression analyses of vertical ground motions are now complete, there are still questions regarding the appropriateness of the form of the regression equation used in the analyses and the estimates of dispersion about the mean. It is anticipated that these remaining questions will lead to further improvements in regression analysis methods and results.

We found that the vertical response spectra derived from regression analyses differ somewhat from those obtained based on ratios (PG&E, 1988); however, in an overall sense, there was excellent agreement. Figure 1 shows that the Program's vertical ground motions equal or exceed our random-effects, unsmoothed regression results at all frequencies at the median level. At the 84th-percentile level, which is controlled by estimates of dispersion about the mean, the Program's vertical ground motions exceed the random-effects regression results by as much as 25 percent at frequencies greater than 10 hertz. At frequencies between 2 hertz and 10 hertz, spectral values of individual frequencies of the unsmoothed random-effects regression results exceed the Program's results by amounts ranging from a few percent at 3.5 hertz to 15 percent at 10 hertz. At frequencies less than 2 hertz, the two methods provide essentially identical results. (The presence of a relatively large spectral peak and trough in the 84th-percentile response spectrum between 2 hertz and 10 hertz indicates that the estimates of dispersion for individual frequencies need further improvement). Overall, the agreement between the Program's results and our random-effects regression results is excellent.

The ratio method used during the Long Term Seismic Program (PG&E, 1988) has been used extensively throughout the engineering community in recent years, and has been the basis for licensing many nuclear power plants. Our 1988 ratio analysis was a significant improvement over earlier, similar analyses in that the vertical-to-horizontal ratio was a function of frequency, rather than a single value applied throughout the frequency range. Because the horizontal motion is well understood, the vertical motions resulting from our application of the ratio method are well constrained. The Program's 1988 analysis represented the industry state of the art.

We believe that the most appropriate vertical response spectra to use for Diablo Canyon analyses are those obtained by the ratio method, as described in our Final Report (PG&E, 1988), because

- the results of the two methods show excellent overall agreement,
- the ratio method is well accepted in the earthquake engineering community, and has been the licensing basis for many nuclear power plants,





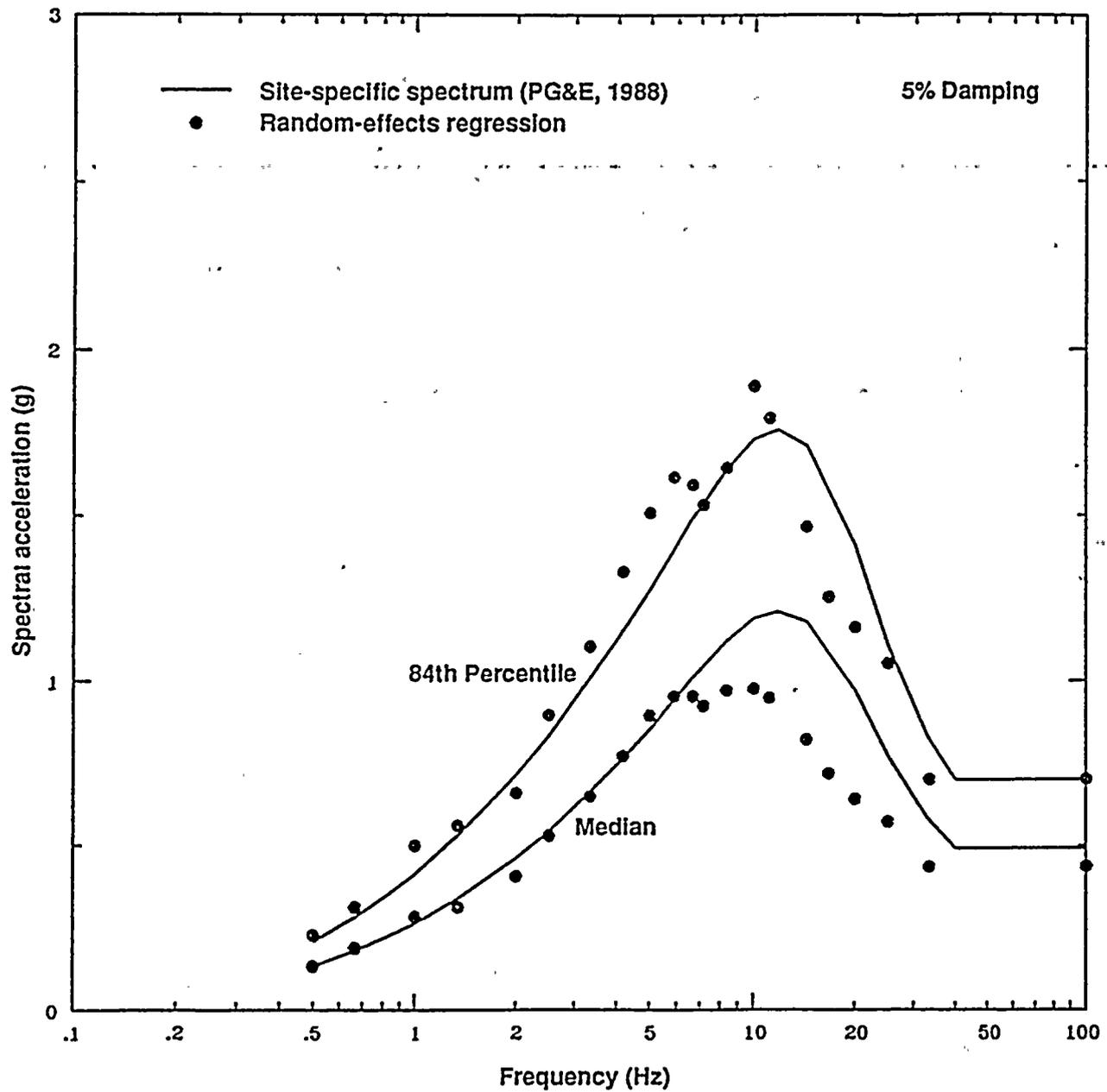


Figure 1

Comparison of the site-specific vertical spectra (PG&E, 1988) with the results of the random-effects regression analyses.



- regression analyses have areas of uncertainty that are still being studied, and when resolved, may well yield different results,
- the horizontal motion is well understood, therefore the vertical motions resulting from our application of the ratio method are well constrained.

#### REFERENCES

Pacific Gas and Electric Company, 1988, Final report of the Diablo Canyon Long Term Seismic Program: U. S. Nuclear Regulatory Commission, Docket Nos. 50-275 and 50-323.



