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Strong nonlinear dependence of the spectral amplification factors of deep Vrancea earthquakes magnitude

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Nonlinear effects in ground motion during large earthquakes have long been a controversial issue between seismologists and geotechnical engineers. Aki wrote in 1993:„Nonlinear amplification at sediments sites appears to be more pervasive than seismologists used to think... Any attempt at seismic zonation must take into account the local site condition and this nonlinear amplification(Local site effects on weak and strong ground motion, Tectonophysics,218,93-111). In other words, the seismological detection of the nonlinear site effects requires a simultaneous understanding of the effects of earthquake source, propagation path and local geological site conditions. The difficulty for seismologists in demonstrating the nonlinear site effects has been due to the effect being overshadowed by the overall patterns of shock generation and path propagation. The researchers from National Institute for Earth Physics ,in order to make quantitative evidence of large nonlinear effects, introduced the spectral amplification factor (SAF) as ratio between maximum spectral absolute acceleration (Sa), relative velocity (Sv) , relative displacement (Sd) from response spectra for a fraction of critical damping at fundamental period and peak values of acceleration(a-max),velocity (v-max) and displacement (d-max),respectively, from processed strong motion record and pointed out that there is a strong nonlinear dependence on earthquake magnitude and site conditions.The spectral amplification factors(SAF) are finally computed for absolute accelerations at 5% fraction of critical damping (=5%) in five seismic stations: Bucharest-INCERC(soft soils, quaternary layers with a total thickness of 800 m);Bucharest-Magurele (dense sand and loess on 350m); Cernavoda Nuclear Power Plant site (marl, loess, limestone on 270 m) Bacau(gravel and loess on 20m) and Iassy (loess, sand, clay, gravel on 60 m) for last strong and deep Vrancea earthquakes: March 4,1977 (MGR =7.2 and h=95 km);August 30,1986(MGR =7.0 and h=130 km);May 30,1990 (MGR =6.7 and h=90 km) and May 31,1990 (MGR =6.1 and h=87 km). With a view to understand the characteristics of nonlinear soil behavior and the nonlinearity in the seismology and the influence to hazard and risk assessment ,this study examined the ways that nonlinearity would expected to appear on strong motion records made on Romania territory during to last Vrancea earthquake. The effect on nonlinearity is very large. For example, if we maintain the same amplification factor (SAF=5.8942) as for relatively strong earthquake on May 31,1990 with magnitude Ms =6,1 then at Bacau seismic station for earthquake on May 30,1990 (MGR =6.7) the peak acceleration has to be a*max =0.154g(+14.16%) and the actual recorded was only, a max =0.135g. Also, for Vrancea earthquake on August 30,1986, the peak acceleration has to be a*max=0.107g (+45,57%), instead of real value of 0.0736 g recorded at Bacau seismic station. More, the spectral amplification factors(SAF) are function of earthquake magnitude and there is a strong nonlinear dependence of the SAF of earthquake magnitude. The median values of SAF of the last strong Vrancea earthquakes for damping 5% are: 4.16; 3.63 and 3.26 corresponding to May 31,1990 Vrancea earthquake (Ms=6.1),May 30,1990 Vrancea earthquake(Ms=6.7),respectively, August 30,1986 Vrancea one(Ms=7.0). At the same seismic station, for example at Bacau, for 5% damping, SAF for accelerations is 5.22 for May 31,1990 earthquake (Ms =6.1);4.32 for May 30,1990 earthquake (Ms =6.7) and 3,94 for August 30,1986 one (Ms=7.0) etc. Finally, it will be made a comment in connection to U.S. Atomic Energy Commission–Regulatory Guide 1.60 on “Design Response Spectra for seismic design of nuclear power plants “ to see spectral amplification factors for deep Vrancea earthquakes are larger and different.