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Nonlinear seismology a reality. The quantitative data

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Nonlinear effects in ground motion during large earthquakes have long been a controversial issue between seismologists and geotechnical engineers. The central point of the discussion in last 10-15 years was whether soil amplification is function of earthquake magnitude. Laboratory tests made by using Hardin or Drnevich resonant columns consistently show the decreasing of dynamic torsion function(G) and increasing of torsion damping function(D%) with shear strains(γ) induced by deep strong Vrancea earthquakes; G = G(γ), respectively, D%= D%(γ),therefore nonlinear viscoelastic constitutive laws are required. ***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*** (Aki, A., Local Site Effects on Weak and Strong Ground Motion, Tecto-nophysics, 218, pp.93-111, 1993). The difficulty to seismologists in demonstrating the nonlinear site effects has been due to the effect being overshadowed by the overall patterns of shock generation and propagation. 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. In main ground motion equation, ground displacement u(t) has general form: u(t)=s(t)*g(t)*i(t),where s(t),g(t) and i(t) are source, propagation and, respectively, instrument recording functions. The authors, in order to make ***quantitative evidence*** of large nonlinear effects, introduced and developed the concept of the nonlinear 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 (ζ %) at ***fundamental period or any other period*** and peak values of acceleration (a_{max}), velocity (v_{max}) and displacement (d_{max}) ,respectively, from processed strong motion records, that are:$(SAF)_a = S_a^{max}/a_{max}$; $(SAF)_v = S_v^{max}/v_{max}$; $(SAF)_d = S_d^{max}/d_{max}$ where: $a_{max} = \ddot{y}(t)_{max}$; $v_{max} = \dot{x}(t)_{max}$ and $d_{max} = x(t)_{max}$.The concept was used for last Stress Test asked by IAEA Vienna for Romanian Cernavoda Nuclear Power Plant, where we recorded last three deep strong Vrancea earthquakes: August 30,1986(M_{GR}=7.0),May 30 (M_{GR}=6.7) and May 31,1990 (M_{GR}=6.2).The spectral amplification factors were: SAF= **4.07** (M_{GR}=7.0); **4.74**(M_{GR}=6.7) and **5.78** (M_{GR}=6.2),function of earthquake magnitude, which are far of that given in Regulatory Guide 1.60 of the U. S. Atomic Energy Commission and accepted by IAEA. The present analysis indicates that the effect of nonlinearity could be very important and if the analysis is made for peak accelerations, it is **48.87%** and for stronger earthquakes it will be bigger**.** The authors are coming with new recorded data which will open up a new challenge for seismologists studying nonlinear site effects in 2-D and 3-D irregular geological structures, leading them to a fascinating research subject in ***nonlinear seismology.***