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From ambient vibrations to damage assessment at urban scale: a numerical study and application to Beirut city (Lebanon)

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Structures having frequencies close to foundation soil frequencies usually exhibit significantly heavier damages, which led several authors to propose specific ground motion intensity measures focusing on the spectral content around the structural frequency. The purpose of the present study is to go one step further and propose some simple tools that could be used at urban scale to provide a quantitative estimation of the damage modulation as a function of site conditions. In that aim, a comprehensive numerical analysis to investigate the effect of coincidence between soil and building frequencies has been performed. A large set (over 100) of 1DOF elastoplastic oscillators representing the various RISK-UE typologies was considered at the surface of hundreds (around 800) of realistic soil profiles. The response of these (site-oscillator) couples were computed for a large number (60) of input waveforms of various PGA levels and frequency contents. The associated damage was quantified according to the RISK-UE recommendations, associating the various EMS98 damage grades to the comparison of maximum oscillator displacement to both yield and ultimate post-elastic displacements. This damage level was then systematically compared to the damage obtained in the case of a similar oscillator located on bedrock and shaken by the same input waveform. The correlation between this soil/rock damage increment and a number of simple site, structural and loading parameters was then analyzed using a neural network approach. The results emphasize the key role played by the ratio between building and site fundamental frequencies, even when both soil and building behave non-linearly; other important parameters are the PGA level, the soil/rock impedance contrast (as proxy to site amplification) and the building ductility. As the impedance contrast is not easily available from field measurements at urban scale, further noise simulation analyses were performed to investigate the performance of H/V amplitude as a statistical proxy to site amplification. The results proved satisfactory, allowing a very easy implementation of this approach on the basis of ambient vibration measurements both at ground level and within buildings. An illustrative example application will be shown for the city of Beirut (Lebanon).