Site effects in strong-impedance environments and the importance of f₀: Lessons learned in Boston, Massachusetts

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ABSTRACT:
In environments with strong impedance contrasts, soil amplification can be significant. Ground motions recorded at the surface and at depth in bedrock during the 2011 Mineral earthquake at a soil site in Boston, Massachusetts, exhibited an amplification ratio of 10 at the fundamental site period (0.7 s). The vertical seismometer array at Northeastern University consists of 51 m of sediments (Vₛ ~ 200-400 m/s) overlying hard bedrock (Vₛ ~ 2000 m/s). To test whether these amplifications persist for design-level ground motions, we performed a series of site-specific ground response studies for typical sites with varying bedrock depth in Boston. The results show that when bedrock depth is near 30 m, the mean short-period and intermediate-period NEHRP site coefficients (Fₐ and Fᵥ, respectively) are consistent with the results of the site-specific ground response study. However, if bedrock depths are less than 30 m, the NEHRP Fₐ significantly underpredicts the soil amplification, and the NEHRP Fᵥ significantly overpredicts the soil amplification. For bedrock depths greater than 30 m, the NEHRP Fₐ and Fᵥ both underpredict the soil amplification. We conclude that modifications to NEHRP site coefficients are needed for strong-impedance environments. Because the soil response in strong-impedance environments is driven by bedrock depth, microtremor studies can be used to identify the fundamental site frequency, f₀. By combining local information on soil profiles and soil velocities in Boston, f₀ can be used to adequately predict soil amplification in Boston.