# Ground motions for engineering

ErSE390 Seismic waves

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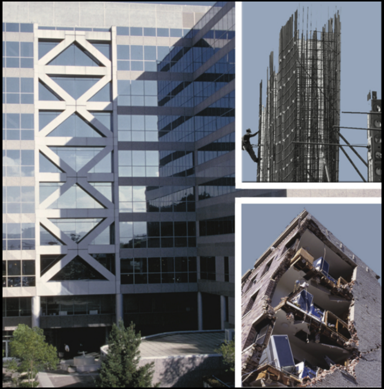
# Primer

Strong seismic shaking can deform railroads, collapse bridges and destroy buildings. It is thus important to estimate the seismic risk, in particular for populated areas, to decide on building norms and how to secure important infrastructure. Let us start looking at seismic wave propagation from an engineering perspective.

# Ground motions for engineering

# Engineering seismology

Engineering seismology is interested in the strong ground motion near earthquakes. Since damage on buildings and infrastructures are primarily due to the acceleration, ground motion at a site is either characterized by **accelerations** or shaking **intensities**, where the latter commonly is the Modified Mercalli Intensity (MMI) scale.



# Characteristics

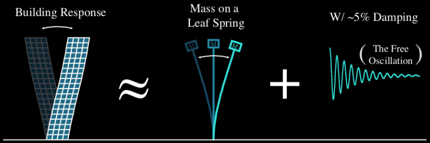
For quantitative analysis, ground motion for engineering is mainly characterized into

| amplitude-based quantities | duration-based quantities |
| --- | --- |
| peak-ground acceleration (PGA), root-mean-square acceleration (RMSA), .. | Arias intensity (AI), Housner intensity, duration of shaking, .. |

Peak acceleration approximately decays as $P(M, r) = a\,10^{b\,M} r^{-c}$ with a, b, c constants depending on rock, event depth, frequency, .. (mostly found by empirical relations).

Motion intensity is defined as $I(t) = \frac{\pi}{2\,g} \int_0^t a^2(\tau) d\tau$ with acceleration $a(t)$ and $g$ the gravitational acceleration. Arias intensity is the maximum value of $I(t)$.

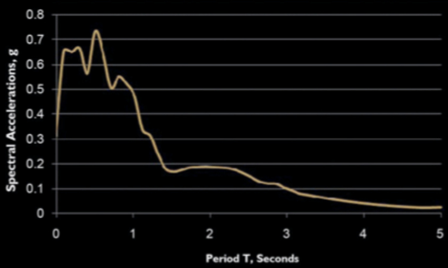
Since the motion of a building is mainly affected by accelerations rather than velocities, the peak-ground acceleration (PGA) has been often used to quantify seismic shaking. An additional quantity more meaningful for building responses is the response spectral acceleration (SA), which gives the maximum acceleration experienced by a damped, single-degree-of-freedom oscillator:




$$\frac{d^2x}{dt^2} + 2\xi\omega_0\frac{dx}{dt} + \omega_0^2\,x = F(t)$$

with $\omega = \sqrt{\frac{k}{m}}$ and $\xi = \frac{c}{2m\omega_0}$, driven by the ground motion $F(t)$.

# Building response



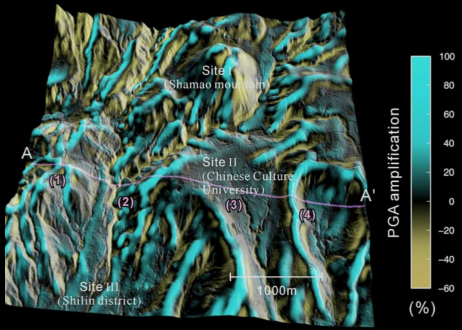

A small building has a resonant frequency of $\sim$0.2 s, a 10-story building of $\sim$1 s.

The response spectral acceleration indicates in which frequency range most of the ground motion energy can cause damage.

Site amplifications are often due to sedimentary layers. For example, the Mexico City event, 1985, was 3 minute shaking at a dominant period of 2 s. Buildings of 6-15 stories were most vulnerable.

# Ground motion amplifications

Ground motions can not only amplify due to local soil properties, but also due to elastic focussing at the surface. As example, topography can amplify ground motions [Lee et al., 2009]:




More accurate modeling can thus help improving seismic hazard analysis with better physics-based ground motion simulations.

More details can be found in these references:


- Lay, T. and Wallace, T. C. (1995).
  ***Modern Global Seismology*.**
  Academic Press.
- Lee, S.-J., Chan, Y.-C., Komatitsch, D., Huang, B.-S., and Tromp, J. (2009).
  **Effects of realistic surface topography on seismic ground motion in the yangminshan region of taiwan based upon the spectral-element method and lidar dtm.**
  *BSSA*, 99:681 – 693.
- Shearer, P. (1999).
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  Cambridge University Press.

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Blackwell Publishing.