Sensitivity of Design Spectrum on Near-Fault Directivity Effects and its Implications on the Design of Common Structural Systems

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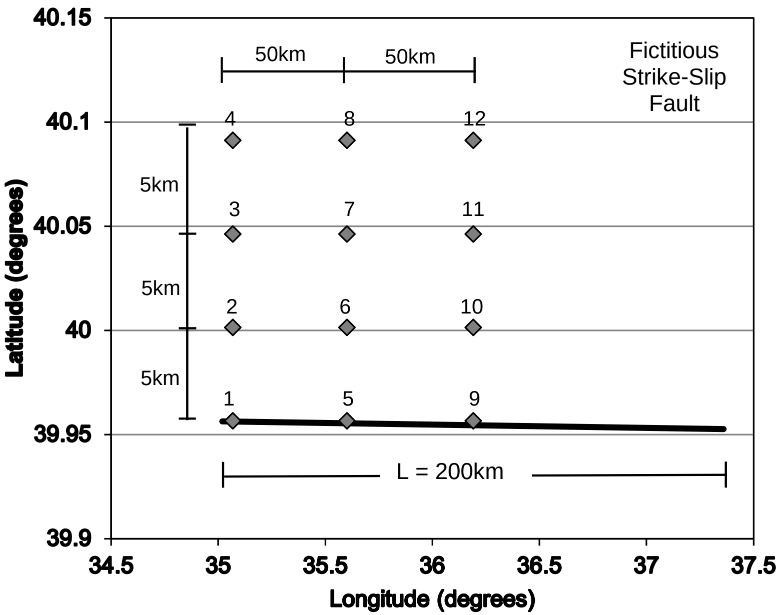
Objective

- To observe near-fault directivity effects through PSHA for a set of sites that are located in the vicinity of a fictitious fault
- To compare the computed spectral amplitude factors (due to directivity) with those of UBC97
- To understand how the structural member dimensions change for common (residential/office) buildings under near-fault directivity effects

Tools

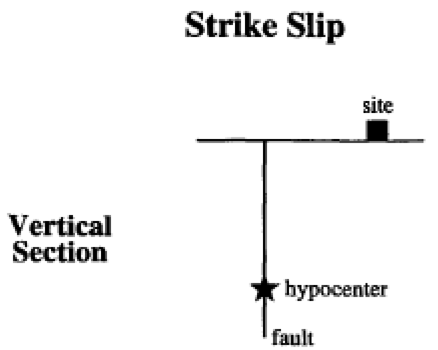
- Earthquake Scenario
- Ground-motion model: Boore and Atkinson (2008) and Sommerville et al. (1997) + Abrahamson (2000)
- EZ-FRISK (PSHA)
- Probina – Orion (design and structural analysis)

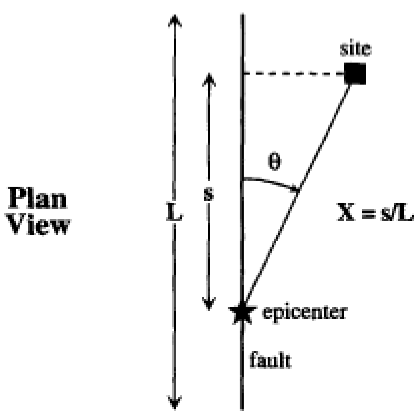
Earthquake Scenario



- Strike-slip fault of 200 km length. Dip angle is 90 degrees. Width is 20 km.
- Slip: 25mm/year
- M_{min}: 5.0, M_{max}: 7.5
- Characteristic recurrence model
- Sites are grey diamonds (12 sites: 5km difference along latitude, 50km difference along latitude)
- All sites are located on a generic rock site (V_{S30} = 760 m/s)

Ground-motion models



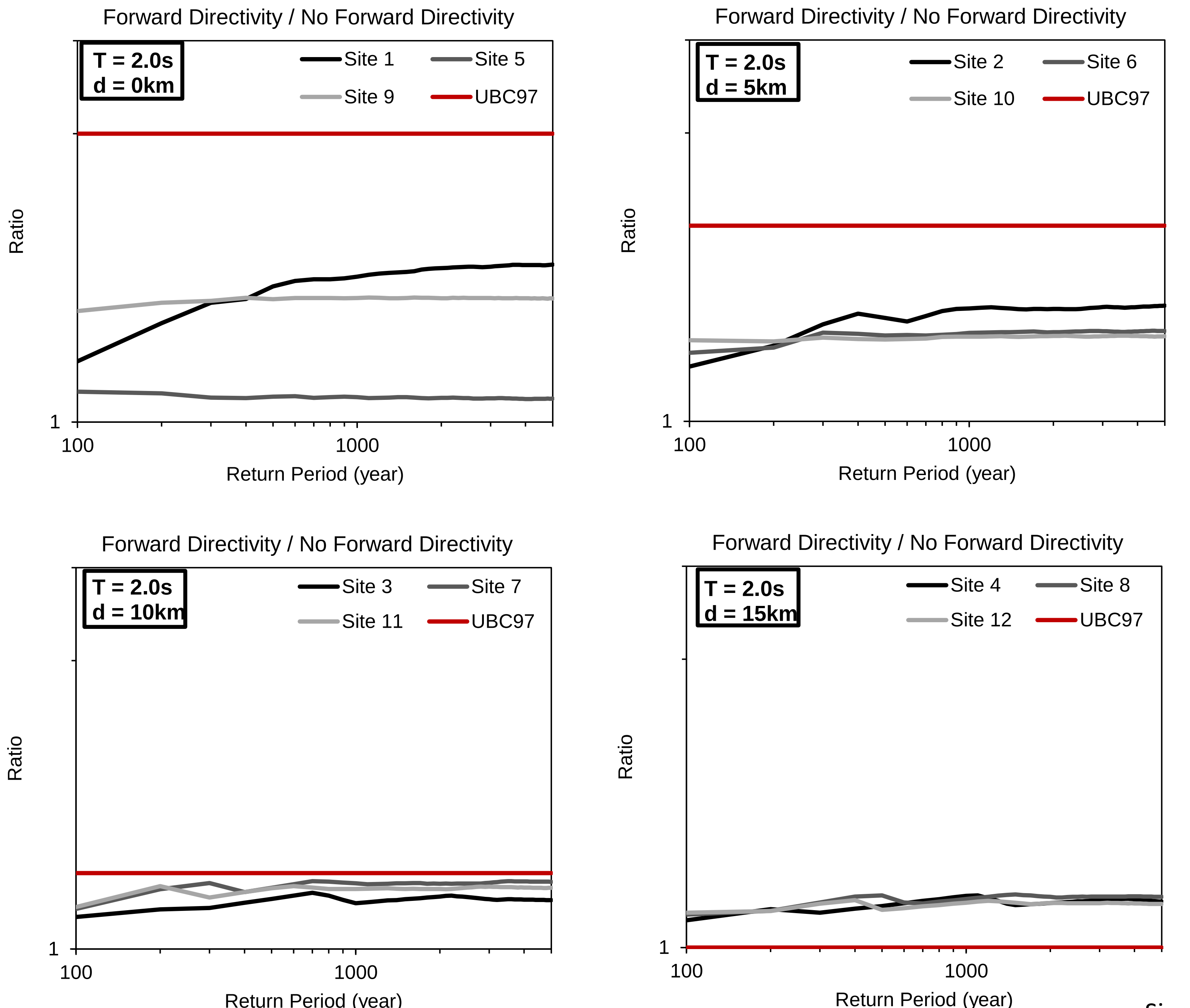


Somerville et al. (1997)

- Conventional GMPE is Boore and Atkinson (2008) [BA08]
- Somerville et al. (1997) + Abrahamson (2000) is to modify BA08 for directivity effects
  - Frequently implemented in the current PSHA applications
  - Applicable to all generic GMPEs
  - Directivity is consider by (a) smaller angle between the directions of rupture propagation and waves traveling from the fault to the site, θ, (b) fraction of the fault rupture to the between the hypocenter and the site, X
  - Model is valid for $M_w \geq 6.5$ for absolute spectral amplitude estimations and $M_w \geq 6.0$ for fault-normal to average spectral ratio.
  - Model does not consider near-fault directivity effects for $R_{rup} > 20$km
  - Forward directivity effects are observed for $T \geq 0.6$s

Evaluation of UBC97 Near-Source Factors

- For a given site:
  - $PSA_{forwarddirectivity}$ / $PSA_{noforwarddirectivty}$ from PSHA at different return periods (T_R) are compared with the UBC97 near-fault factors
- $PSA_{forwarddirectivity}$ refers to fault-normal component
- UBC97 near-source factors are computed for Seismic Source A (slip-rate $\geq$ 5mm/year). Such faults can generate earthquakes of $M_w \geq 7.0$


Forward Directivity / No Forward Directivity
T = 2.0s
d = 0km
Site 1
Site 5
Site 9
UBC97
Ratio
1
100
1000
Return Period (year)
Forward Directivity / No Forward Directivity
T = 2.0s
d = 5km
Site 2
Site 6
Site 10
UBC97
Ratio
1
100
1000
Return Period (year)
Forward Directivity / No Forward Directivity
T = 2.0s
d = 10km
Site 3
Site 7
Site 11
UBC97
Ratio
1
100
1000
Return Period (year)
Forward Directivity / No Forward Directivity
T = 2.0s
d = 15km
Site 4
Site 8
Site 12
UBC97
Ratio
1
100
1000
Return Period (year)

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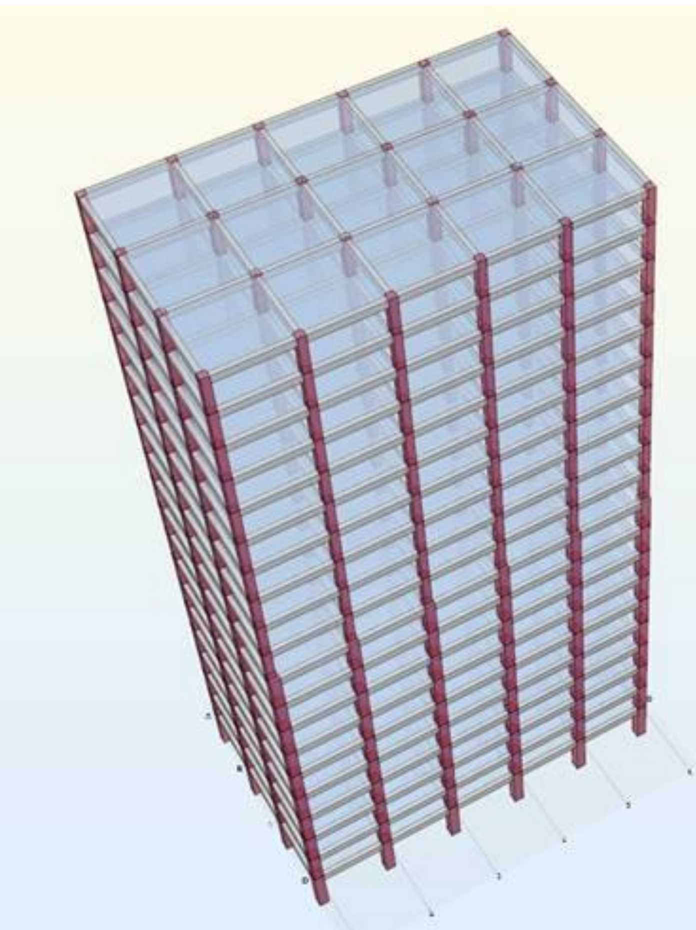
Major Remarks (limited to the case study)

- UBC97 near-source factors are conservative at short distances and at short periods
- Discrepancy between the case study results and UBC97 factors decreases towards larger distances and longer periods. However, UBC97 near-source factors are still larger than those computed in the case study

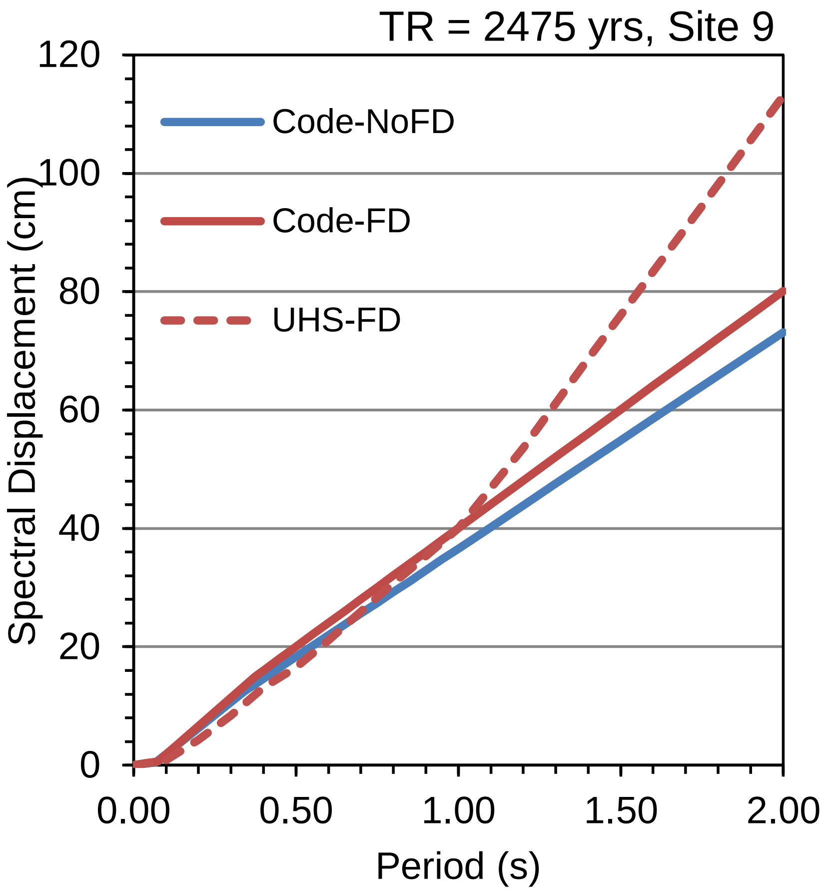
Major Conclusion

- Simplified UBC97 approach to account for near-fault effects is practical in many aspects. However, it may fail to reflect actual seismic demands
- Models adjusting non-directivity GMPEs (such as the one presented here or many others that were developed or under development) can be used to come up with simplified directivity-sensitive code spectra.

Code-based design for buildings located in the vicinity of faults

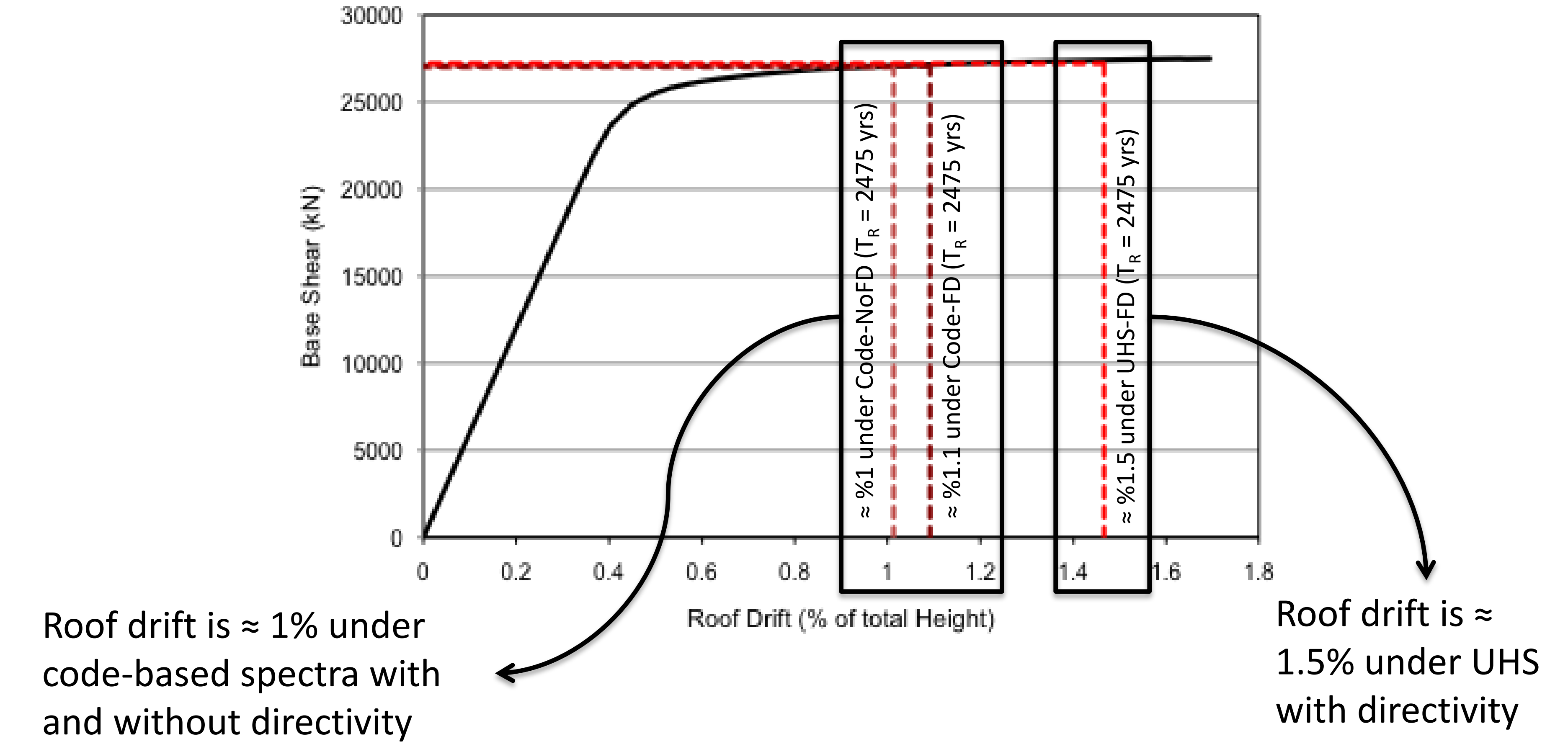


- PSHA results at T = 0.2s and 1.0s are used to construct the design spectrum for designing a 20-story RC office building located at Site 9 (the most critical site in terms of directivity effects in this study).
- Design spectrum is 2/3 of T_R = 2475 years spectrum
- Provisions of Turkish Earthquake Design code are considered in design.
- Building is designed twice by considering directivity and no-directivity effect separately.



- Target ductility is chosen as normal ductile behavior (R, strength reduction factor, is 4 in design). Fundamental period (T_1) of the building is ~ 1.9s.
- When direct code approach is used to establish the design spectrum (i.e., PSA at T = 0.2s and T = 1.0s), directivity effects cannot be identified very well (**blue** and **red** curves with respect to **red-dashed** curve derived from UHS)
- Thus, no change in the structural dimensions when direct code approach is used to for design spectrum

Performance under Directivity (FD) and No-directivity (NoFD) spectra of T_R = 2475 yrs



Even if the building is not designed for the demands described by UHS, the building does not collapse due to its reserved capacity

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Final Remarks

- Definition of near-fault directivity effects for code-based spectrum requires further studies.
- A close collaboration between engineers and seismologists is needed for these studies to consider the complexity of the problem from both engineering and seismological points

Thank you