Near-Source Factors - History

- Mid-1980's. Base Isolation Subcommittee of the Northern Section of SEAOC develops N factors (velocity domain) for design of isolated structures; factors are subsequently adopted by SEAOC for the 1990 SEAOC *Blue Book* and by ICBO for the 1991 *UBC:*
  - Tentative Seismic Isolation Design Requirements, Kircher et al., *Proceedings of the 55th Annual Convention*, September 25-28, 1986, SEAOC Sacramento, California.
  - "Tentative General Requirements for the Design and Construction of Seismic-Isolated Structures," Appendix 1L of the 1990 SEAOC *Blue Book.*

- 1993 - 1994. Ad Hoc Ground Motion Committee of the SEAOC Seismology Committee develops domain-dependent N factors (i.e., Na and Nv factors) for design of all types of structures (prior to 1994 Northridge and 1995 Kobe earthquakes):
  - "An Acceptable Method for Characterizing Seismic Hazard, Status of the Ad Hoc Ground Motion Committee, SEAOC Seismology Committee," Kircher et al., *Proceedings of the 62nd Annual Convention,* September 29 - October 2, 1993, SEAOC, Sacramento, California.

- 1994 - 1995. SEAOC Seismology Committee incorporates N factors into the Strength Design Proposal, Appendix C of 1996 *Blue Book,* subsequently adopted by ICBO for 1997 *UBC:*
  - "1997 UBC: New Ground Shaking Criteria," Kircher, *Proceedings of the 66th Annual Convention,* September 25-27, 1997, SEAOC, Sacramento, California.
  - "New Ground Shaking Design Criteria" 1998, *Structural Engineering World Wide* 1998, *Proceedings o/the Structural Engineers World Congress* (Amsterdam, The Netherlands: Elsevier Science B.V .)

Near-Source Factors - 1997 UBC

- Ground Motion Contours. Factor Seismic Zone 4 ground motion as a function of site proximity to active fault(s):
  - Extension of *UBC* "Near-Field" factors required for design of base-isolated buildings.
- Median Ground Motions. Factors derived from median estimates of empirical ground motion formulas (Boyer/Joyner and Sadigh et al.) based on moment magnitude of fault type.
- Discrete Fault Types. Based on <u>maximum</u> moment magnitude (M) and annual slip rate (SR):
  - Type "A" - moment magnitude, $M \geq 7.0$ <u>and</u> $SR > 5$ mm/year (N based on $M = 7.5$).
  - Type "B" - not Type A or C fault (N based on $M = 7.0$).
  - Type "C" - moment magnitude, $M < 6.5$ <u>and</u> $SR \leq 2$ mm/year (not included).
  - Same factors for strike-slip and reverse-slip faults - increase based on average of strike- slip and reverse-slip formulas.
- Domain Dependent. Different Na and Nv factors for short-period (acceleration domain) and long-period (velocity domain) structures, respectively - consistent with soil factors.
- Directivity Effects. Long-period, Nv, factors bumped by about 20% for <u>average</u> increase in the fault-normal direction of ground shaking - not "worst-case" of the forward-directivity scenario.
- Spectrum Shape. Na and Nv factors applied uniformly over respective acceleration and velocity domains
  - Some near-source records suggest non-uniform effect in the velocity domain (i.e., spectra consistently deviate from the l/T shape in the velocity domain).

Near-Source Factors - Spectrum Shape

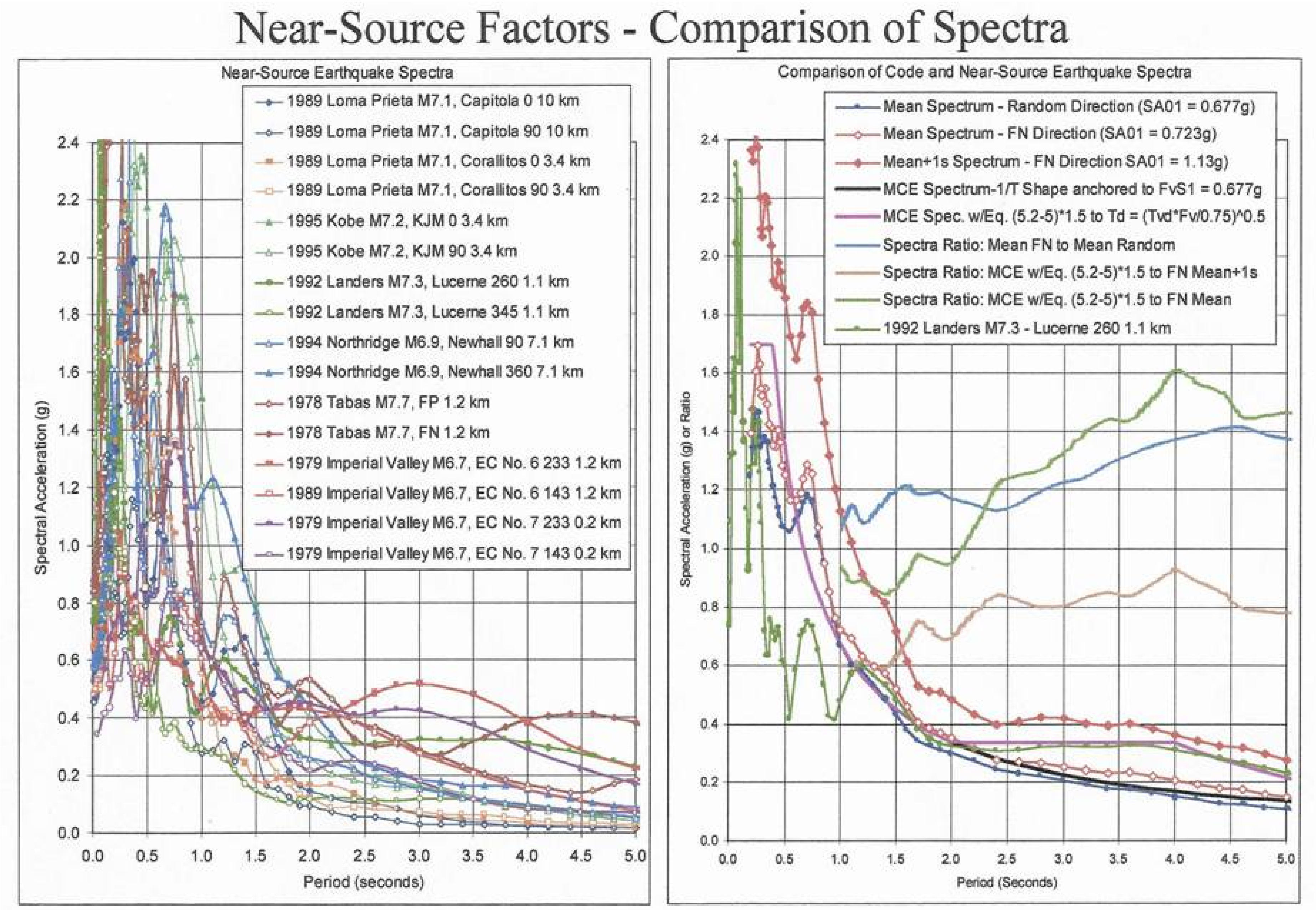
- SEAOC Seismology, 1994 - 1995, considered modifying the l/T shape of the design spectrum to incorporate an "acceleration plateau" at very long periods. Such plateaus appear in certain near-source spectra (e.g., spectra from the El Centro Array, 1985 Imperial Valley earthquake, and spectra of Landers, Turkey and Taiwan records shown in Figure 1 of "Magnitude Scaling of the Near Fault Rupture Directivity Pulse," Somerville).
  - Proposed acceleration plateau, SA = 0.8Ca (Nv > 1) would extend from period, Tv = Cv/0.8Ca to period Td, transition period to the displacement domain, SA = $0.8CaTd^2/T^2$.
    - Proposed modified spectrum shape immortalized by Bachman (Chair) on green commemorative coffee mug distributed to Seismology Committee members (trivia).
  - Design spectrum was not modified, but acceleration plateau was used to define a new minimum base shear requirement for near-source sites, V > 0.8ZNv(W/(R/I)).
- *NEHRP Provisions* incorporated the SEAOC/UBC minimum base shear requirement for design of SDC E and F structures (at sites with S1 > 0.75). The seismic response coefficient, Cs, is governed by Eq. (5.2-5) of the reformatted version of the 2003 *NEHRP Provisions:*
  - Eq. (5.2-5) requires Cs > 0.5S1/(R/I) assuming that 0.5 of MCE spectral acceleration, Sl, is approximately equal to 2/3 of 0.8 of DBE spectral acceleration, ZNv.
  - Eq. (5.2-5) does not recognize the transition at very long periods to the displacement domain, penalizing the design of very tall, flexible (SDC E and F) structures.
  - Eq. (5.2-5) is not excluded from the calculation of drift, affecting large drift demands on very tall, flexible (SDC E and F) structures.

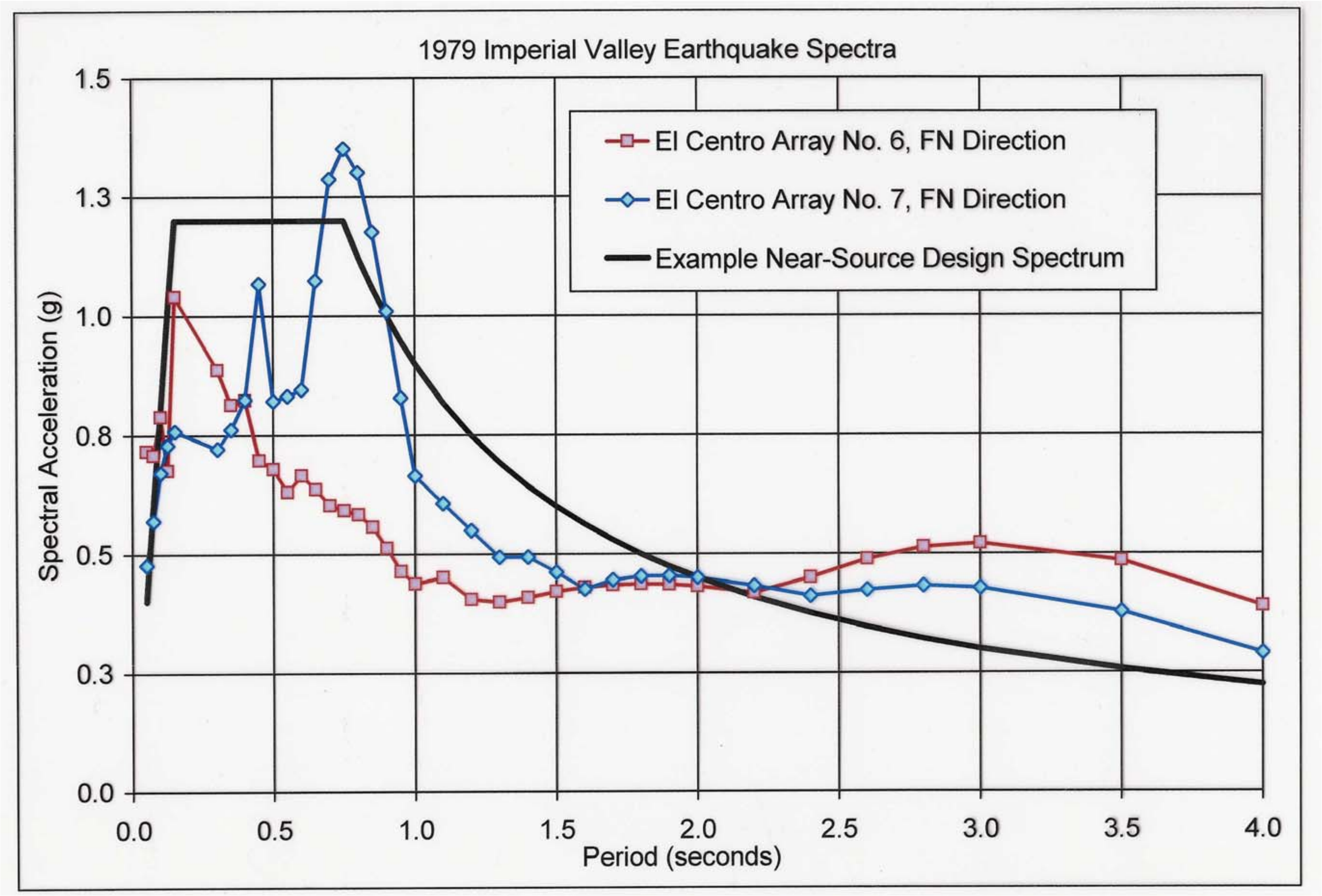
Near-Source Factors – Issues (2003 *NEHRP Provisions*)

- Should the median-based mapped spectral acceleration parameters be increased to account for near-source effects (i.e., fault normal versus average ground motions)?
  - The near-source factor, Nv, of the 1997 *UBC* includes about a 20% increase (above median ground motions) to account for the average increase in fault-normal ground shaking.
- Should the increase, if any, apply only to SDC E and F structures (i.e., S1 > 0.75 g)?
- Should the increase, if any, be based on the magnitude of the source and the distance of the source to the site?
  - Studies of recorded motions indicate some dependence on magnitude and significant dependence on distance (see for example ratios of strike-normal to average response spectra shown in Figure 13 of *Seismological Research Letters* paper by Somerville, Smith, Graves and Abrahamson, SSA, *SRL* Vol. 68, Number 1.)
- Should the increase, if any, be applied uniformly to the velocity domain or reflect the strong period-dependence (i.e., non-l/T shape) of certain spectra of near-source records?
  - Figure 13 of 1997 *SRL* paper by Somerville et al. indicates the ratio of FN/Average spectral response for sites close to fault rupture increases from about 1.1 at a period of 1 second to about 1.5 at periods of 4 seconds and greater.
- Should the increase, if any, be a function of the importance (SUG) of the structure (e.g., require increase only, or greater increase, for SUG III = SDC F structures)?
- Drift Demand. If design ground motions are modified, or otherwise deemed, to appropriately incorporate near-source effects, then drift demand on the structure would directly account for such effects, and Eq. (5.2-5) could be dropped from the *NEHRP Provisions.*

Near-Source Factors - Comparison of Spectra

- Figure (on left side of following page) showing 16 near-source spectra:
  - Set of 16 response spectra of 8 records, 2 components each, representing approximately fault normal (stronger direction) and fault parallel (weaker direction) ground shaking.
  - Average distance to fault rupture is about 3.5 km, distances vary from 0.2 to 10 km.
  - Average event magnitude is about M = 7.1, magnitudes vary from M = 6.7 to M = 7.7
  - Average 1-second spectral acceleration, Fv x S1 = 0.677g, is low (less than S1 = 0.75 g).
- Figure (on right side of following page) comparing shapes of near-source spectra:
  - Comparison of mean or mean plus 1 sigma spectra of either FN or all (both FN and FP) records with MCE design spectra anchored to the mean of the 16 records at 1 second.
  - MCE spectrum w/Eq. (5.2-5). MCE design spectrum (l/T) shape modified to include an acceleration plateau, consistent with Eq. (5.2-5) acceleration (factored by 1.5 to represent MCE spectral demand), that transitions to the displacement domain at Td = 4 seconds, such that spectral displacement is consistent with Tvd = 8 seconds (of the l/T spectrum).
  - Ratio of mean of fault normal (FN) spectra to mean of all (average) spectra varies from about 1.1 at 1 second to about 1.4 at 4 seconds, consistent with Figure 13 (Somerville).
  - Ratio of MCE spectrum w/Eq. (5.2-5) plateau to fault normal (FN) spectra:
    - Conservative for mean of fault normal spectra, 20% (2 seconds) to 40% (4 seconds).
    - Non-conservative for mean plus 1 sigma of fault normal spectra.
  - MCE Spectrum w/Eq. (5.2-5) plateau has the same long-period shape as the fault normal (260 degree) component of the Lucerne record of the 1992 Landers earthquake.


Near-Source Factors - Comparison of Spectra
Near-Source Earthquake Spectra
1989 Loma Prieta M7.1, Capitola 0 10 km
1989 Loma Prieta M7.1, Capitola 90 10 km
1989 Loma Prieta M7.1, Corallitos 0 3.4 km
1989 Loma Prieta M7.1, Corallitos 90 3.4 km
1995 Kobe M7.2, KJM 0 3.4 km
1995 Kobe M7.2, KJM 90 3.4 km
1992 Landers M7.3, Lucerne 260 1.1 km
1992 Landers M7.3, Lucerne 345 1.1 km
1994 Northridge M6.9, Newhall 90 7.1 km
1994 Northridge M6.9, Newhall 360 7.1 km
1978 Tabas M7.7, FP 1.2 km
1978 Tabas M7.7, FN 1.2 km
1979 Imperial Valley M6.7, EC No. 6 233 1.2 km
1989 Imperial Valley M6.7, EC No. 6 143 1.2 km
1979 Imperial Valley M6.7, EC No. 7 233 0.2 km
1979 Imperial Valley M6.7, EC No. 7 143 0.2 km
Spectral Acceleration (g)
Period (seconds)
Comparison of Code and Near-Source Earthquake Spectra
Mean Spectrum - Random Direction (SA01 = 0.677g)
Mean Spectrum - FN Direction (SA01 = 0.723g)
Mean+1s Spectrum - FN Direction SA01 = 1.13g)
MCE Spectrum-1/T Shape anchored to FvS1 = 0.677g
MCE Spec. w/Eq. (5.2-5)*1.5 to Td = (Tvd*Fv/0.75)^0.5
Spectra Ratio: Mean FN to Mean Random
Spectra Ratio: MCE w/Eq. (5.2-5)*1.5 to FN Mean+1s
Spectra Ratio: MCE w/Eq. (5.2-5)*1.5 to FN Mean
1992 Landers M7.3 - Lucerne 260 1.1 km
Spectral Acceleration (g) or Ratio
Period (Seconds)


1979 Imperial Valley Earthquake Spectra
El Centro Array No. 6, FN Direction
El Centro Array No. 7, FN Direction
Example Near-Source Design Spectrum
Spectral Acceleration (g)
1.5
1.3
1.0
0.8
0.5
0.3
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Period (seconds)