ASSESSMENT OF SEISMIC DESIGN LOADS

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VIBRATORY GROUND MOTION

- Vibratory ground motion due to earthquake
- Vibratory ground motion due to excavation
- Vibratory ground motion due to thermal loading
- Vibratory ground motion due to explosions
  - underground nuclear explosions
  - surface explosions and missle impacts

VIBRATORY GROUND MOTION DUE TO EXCAVATION

- Induced seismicity due to stress perturbations resulting from material extraction

- Significant levels generally associated with deep excavations (> 1 km) and high values of extraction

- Due to relatively shallow depth of repository, not considered a significant issue

VIBRATORY GROUND MOTION DUE TO THERMAL LOADING

- Induced seismicity due to stress perturbations resulting from thermal load

- Combined analytical/empirical approach to estimate levels of activity (frequency-magnitude)

  - Thermo/mechanical modeling to estimate expected stress perturbations

  - Studies of RIS to relate seismicity to effects of impoundment on local stress field.

APPROACHES FOR SPECIFICATION OF DESIGN GROUND MOTIONS

- Deterministic approaches
- Probabilistic approaches
- Combined deterministic and probabilistic approaches
- Treatment of uncertainty

DETERMINISTIC APPROACHES FOR ENGINEERING CHARACTERIZATION OF DESIGN GROUND MOTION DUE TO EARTHQUAKES

- Explicit identification and evaluation of

  - all seismic sources (magnitudes and distances)

  - propagation path effects (attenuation relations)

  - site effects (local site specific amplification)

DETERMINISTIC APPROACHES FOR ENGINEERING CHARACTERIZATION OF DESIGN GROUND MOTION DUE TO EARTHQUAKES

- Empirical methods
- Theoretical methods
- Calibrated theoretical methods
- Stochastic methods
- Recommended approach

EMPIRICAL METHODS FOR ENGINEERING CHARACTERIZATION OF DESIGN GROUND MOTION DUE TO EARTHQUAKES

- Data Needs
  - Site independent

    Direct regression on recorded data
  - Site dependent (statistical)

    Average of representative data

    mag, dist, site conditions
    scale than average

- Indirect empirical relationships

  use of data from instruments other than strong ground motion: attempts to determine how motion scale with distance for a given region

- Calibrated empirical relationships

  model which describes the regional dependence of strong motion attenuation with distance to convert or scale to the region of interest

EMPIRICAL METHODS FOR ENGINEERING CHARACTERIZATION OF DESIGN GROUND MOTION DUE TO EARTHQUAKES

- Indirect Empirical
  - Use of non-strong motion data
  - Apply to low seismicity areas
  - Attempt to determine how motions scale with distance for a given region
  - Infer strong ground motion scales in a similar manner

- Calibrated Empirical
  - Assume strong ground motions are region independent at close distance (<50 km)
  - Use an attenuation model which accommodates the regional differences in attenuation to correct or scale to the region of interest

THEORETICAL METHODS FOR ENGINEERING CHARACTERIZATION OF GROUND MOTION DUE TO EARTHQUAKES

- PURELY THEORETICAL

  - Complete anlytical model for strong ground motion
  - Useful for studying source physics
  - Many parameters, non-robust, poorly calibrated
  - too deterministic

- SEMI THEORETICAL

  - Combine analytical and empircal
  - Uses simple analytical model with recorded motions
  - Few free parameters, robust, well-calibrated

CALIBRATED THEORETICAL METHODS FOR ENGINEERING CHARACTERIZATION OF DESIGN GROUND MOTION DUE TO EARTHQUAKES

- Assumes very simple earthquake source scaling relation
- Calibrate with small earthquakes
- Early attempts in predicting strong motions in the central and eastern United States
- Too simple, high uncertainty

STOCHASTIC METHODS FOR ENGINEERING CHARACTERIZATION OF GROUND MOTION DUE TO EARTHQUAKES

- Earthquake ground motions are random "gaussian" noise
- Theoretically based seismic source and propagation path parameters
- Estimate parameters with small earthquake data
- Simple, few parameters, robust, well-calibrated

RECOMMENDED APPROACH FOR ENGINEERING CHARACTERIZATION OF GROUND MOTIONS DUE TO EARTHQUAKES

- Emphasis on empirical and statistical
- Stochastic
- Semi-empirical

PROBABILISTIC METHODS FOR ENGINEERING CHARACTERIZATION OF GROUND MOTION DUE TO EARTHQUAKES

- Explicitly include alternate models

  - source models (style of faulting, activity rates,...)

  - ground motion models (attenuation relations)

  - site effects (soil amplification models)

- Formal treatment of uncertainty

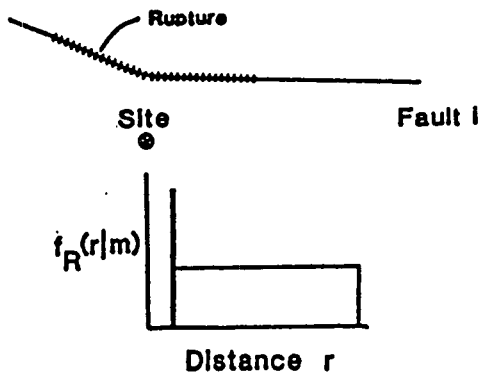
  - accommodate dispersion in ground motion models

PROBABILISTIC METHODS FOR ENGINEERING CHARACTERIZATION OF GROUND MOTION DUE TO EARTHQUAKES

- Characterization of earthquake sources
  - Location and geometry
  - Earthquake recurrence
  - Maximum expected events
- Probabilistic analysis
- Treatment of uncertainty

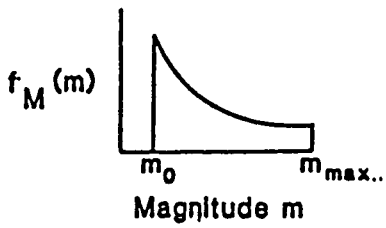
- Results in a hazzard curve which properly addresses alternative models as well as uncertainty in the models

A. Seismic Source I
(Earthquake locations in space lead to a distribution of epicentral distances $f_R(r|m)$



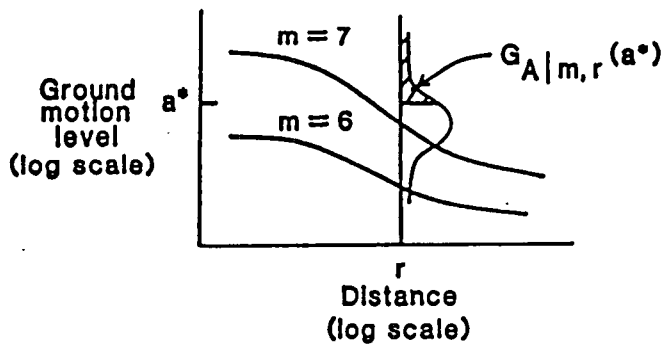
B. Magnitude distribution and rate of occurrence for Source I:

$f_M(m), \nu_I$



C. Ground motion estimation:

$G_{A|m,r}(a^*)$



D. Probability analysis:

$$P[A > a^* \text{ in time } t]/t = \sum_I \nu_I \iint G_{A|m,r}(a^*)\, f_M(m)\, f_R(r|m)\, dm\, dr$$

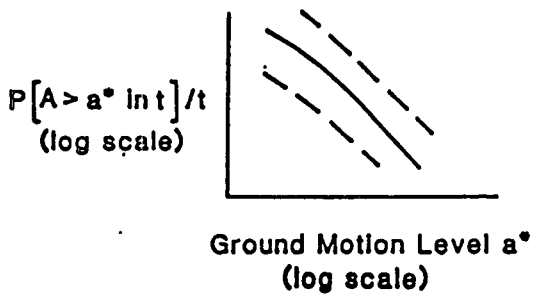
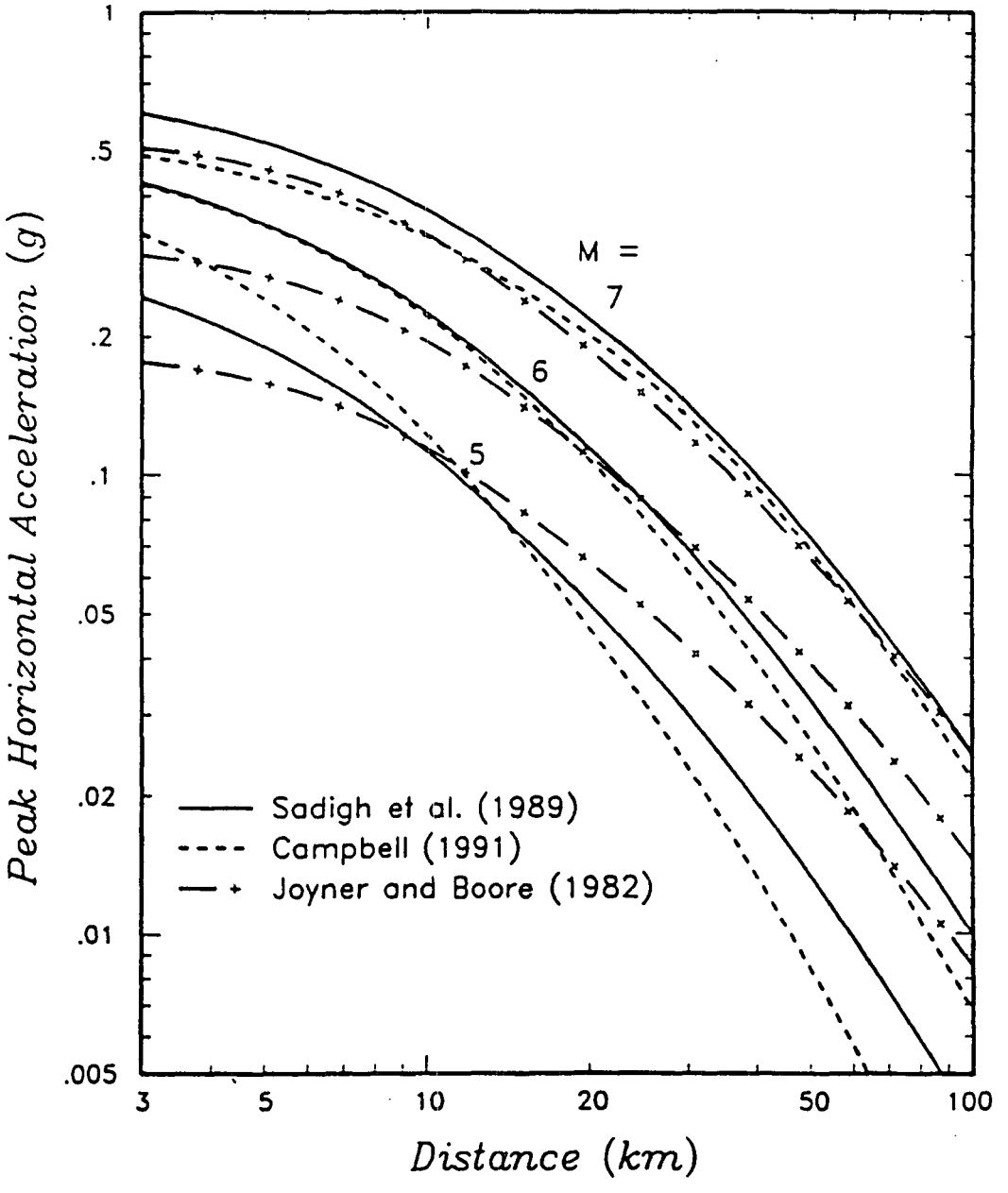
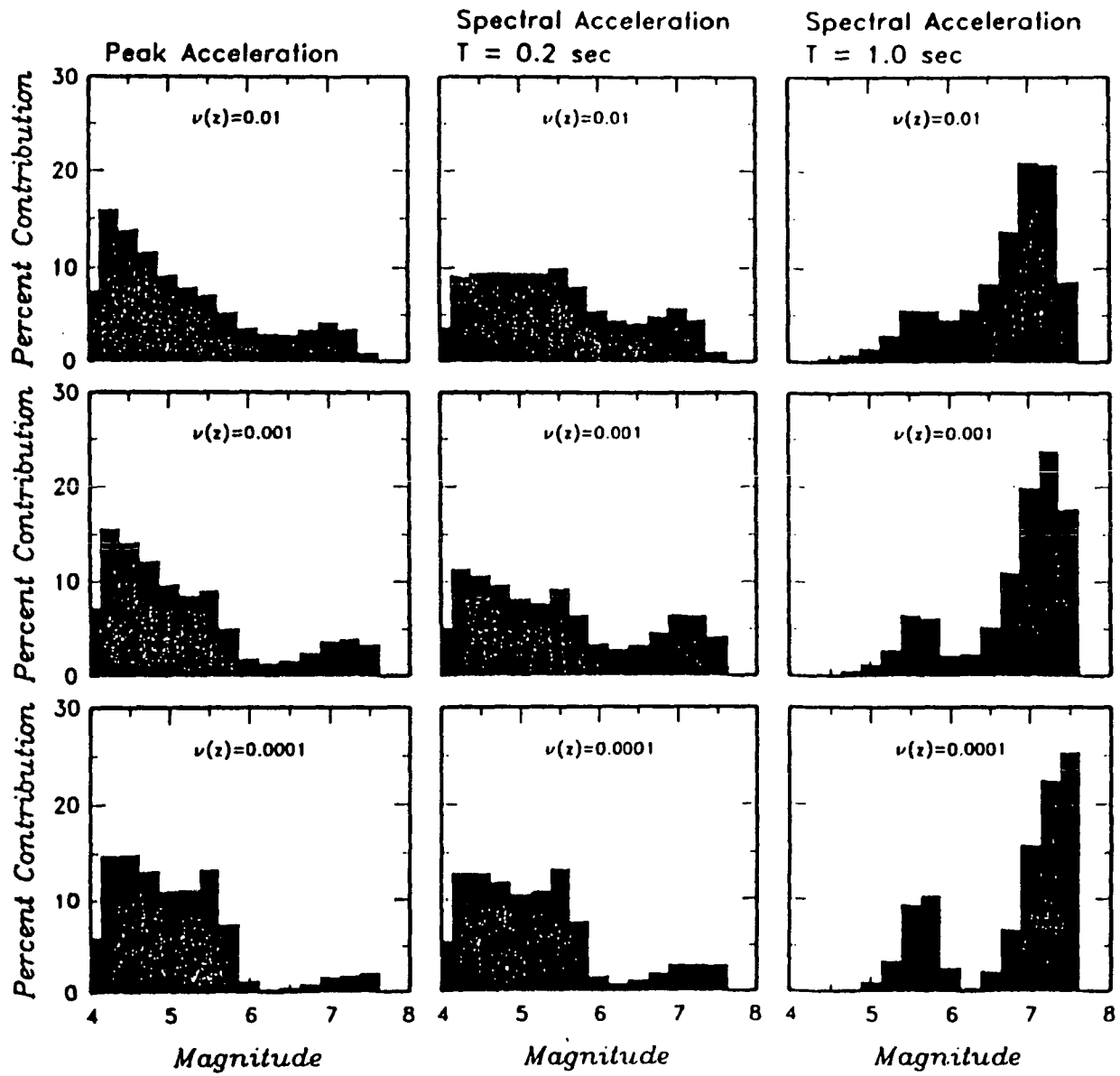


FIGURE 1: Steps in probabilistic seismic hazard methodology.


Peak Horizontal Acceleration (g)
1
.5
.2
.1
.05
.02
.01
.005
3
5
10
20
50
100
Distance (km)
M =
7
6
5
Sadigh et al. (1989)
Campbell (1991)
Joyner and Boore (1982)

ENGINEERING CHARACTERIZATION OF DESIGN GROUND MOTION DUE TO EARTHQUAKES

- Recommended approach
- Rationale for combining deterministic and probabilistic approaches


Peak Acceleration
Spectral Acceleration
T = 0.2 sec
Spectral Acceleration
T = 1.0 sec
Percent Contribution
ν(z)=0.01
ν(z)=0.001
ν(z)=0.0001
0
10
20
30
4
5
6
7
8
Magnitude

ENGINEERING CHARACTERIZATION OF GROUND MOTION DUE TO UNDERGROUND EXPLOSIONS

- Construct ground motion model

  (how ground motions change with yield, depth, and distance)

  - Requires large data set of recorded motions

  - Reasonably well constrained at NTS

ENGINEERING CHARACTERIZATION OF DESIGN GROUND MOTION IN THE SUBSURFACE

- Specify control (design) motions at an outcrop of competent rock
  - shear-wave velocity exceeding 2000-3000 ft/sec
  - preferably at the repository ground surface

- Propagate control motions to depth of interest
  - proper accommodation of appropriate wavefields
  - vertical/inclined compressional- and shear- waves

- Site geotechnical characterization
  - accurate representation of three dimensional variability of dynamic material properties

RECOMMENDATIONS FOR ASSESSMENT OF VIBRATORY GROUND MOTION

- Combined probabilistic/deterministic approach

- Empirical ground motion models supplemented with well-calibrated analytic methods