Seismic Hazard Analysis for Important Engineering Structures

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Seismic Hazard Analysis for Important Engineering Structures

- Seismic Hazard Analysis Methods

1.Deterministic SHA

(1) tectonic method

(2) maximum historical earthquake method

2. Probabilistic SHA

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- Relations between DSHA and PSHA

  Both DSHA and PSHA utilize same basic seismological materials and recognition to evaluate seismic risk, so they are related each other closely.

  (1) source similarity

  Seismogenic Structure

  Diffuse Seismicity

  (2) coordinates

  PSA(potential seismic area)--- Seismogenic Structure

  BE(background earthquake)--- Diffuse Seismicity

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Problems in Seismic Hazard Analysis

- How to divide earthquake statistical unit

  the relation between unit size and sample number in each unit

- Uncertainty in seismic parameters
- How to evaluate the results with lower probability (long return period)

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How to determine design earthquake (scenario) for important engineering structures according to SHA results?

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Damaged building in Kobe

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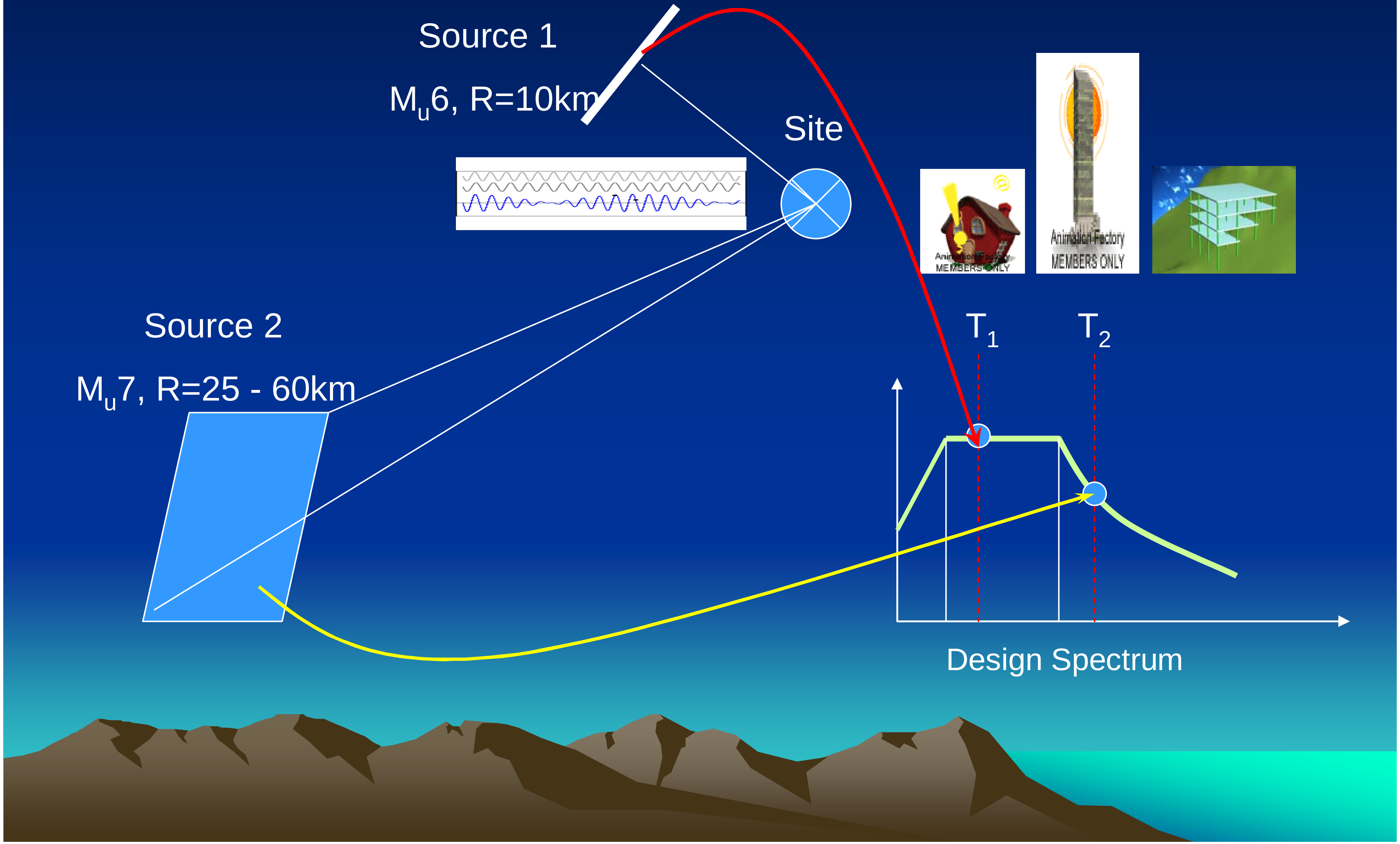
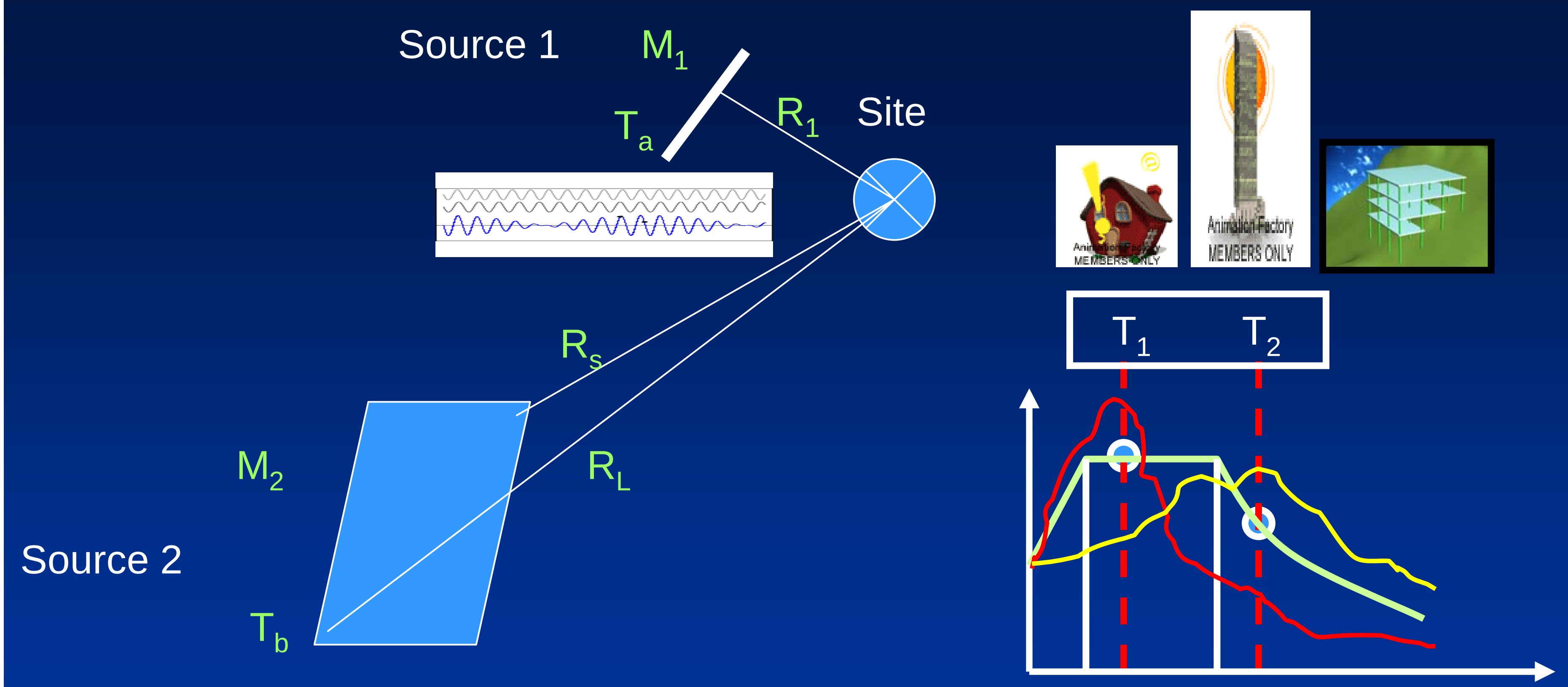
Question?

If all structures in one site should use same design earthquakes in structural aseismic design

Present SHA method result is not related with structural characters, but it is used directly in structural design.

Case Studies





Note: In one source, near- and far-distances might cause the same PGA but different response spectral behaviors as frequency changing. So different (M,R) combination should be considered in one source.

For example: Source 2, (M7, R60) → PGA=100cm/s^2 but different spectra
(M6, R25)

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Present methods to determining design earthquake

（1） Ishikawa,Kameda

$$M^* = \sum_i \sum_j m_i P_k \left[m_i, r_j \mid A \geq a(p) \right] \cdot P_k \left[M = m_i \right] \cdot P_k \left[R = r_j \right]$$

$$R^* = \sum_i \sum_j r_j P_k \left[m_i, r_j \mid A \geq a(p) \right] \cdot P_k \left[M = m_i \right] \cdot P_k \left[R = r_j \right]$$

(2) M.T.Gao

$$\overline{M} = \sum_{j=1}^{N_m} \frac{m_j N_{m_j} P_{lm}\left(m_j\right)}{N_S Q}$$

$$\overline{R} = \sum_{j=1}^{N_m} \frac{R_j N_{m_j} P_{lm}\left(m_j\right)}{N_S Q}$$

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Present methods to determining design earthquake

(3) Q.F.Luo

$$\overline{M_k}(p_0) = \sum_i m_i P_k \left[m_i \mid Y = y(P_0) \right]$$

$$\overline{R_k}(p_0) = g\left[\overline{M_k}(p_0), y(P_0) \right]$$

(4) Z.J.Han

$$M = \frac{M_{0.1} \cdot W_{0.1} + M_{1.0} \cdot W_{1.0}}{W_{0.1} + W_{1.0}}$$

$$R = \frac{R_{0.1} \cdot W_{0.1} + R_{1.0} \cdot W_{1.0}}{W_{0.1} + W_{1.0}}$$

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Present methods to determining design earthquake

(5) Mc Guire

$$M = \sum_{m} M \cdot P[Y \geq y(p_0) \mid M] \cdot P[M]$$

$$R = \sum_{r} R \cdot P[Y \geq y(p_0) \mid R] \cdot P[R]$$

(6) others

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- Suggested structure-based design earthquake

Step 1 choosing design parameter

EPA (effective peak acceleration) $EPA = S_a / 2.5$

Step 2 Calculating exceeding probability of each PSA

$$P_l\left(Y \geq y\right) = 1 - \exp\left\{ -\frac{2\nu}{\beta} \iiint \sum_{j=1}^{N_m} f(m_j) f_{l,m_j} / S_l \cdot P_l\left(Y \geq y \mid E\right) f_l(\theta) \mathrm{SH}\left(\frac{1}{2}\beta\Delta m\right) dxdydz \right\}$$

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Step 3 Calculating magnitude contribution probability of each PSA at period $\bar{T} = \sum_{i=1}^{q} w_i T_i$ $w_i = \gamma_i / \sum_{i=1}^{q} \gamma_i$

$$P_l\left(m_j \mid Y \geq y\right) = \frac{1}{Q} P_l\left(m_j\right) \cdot P_S\left(m_j \mid Y \geq y\right)$$

Step 4 Calculating distance R according to above M design earthquake (M,R)

Step 5 Simulating ground motion according to design earthquake

Step 6 Choosing accelerogram

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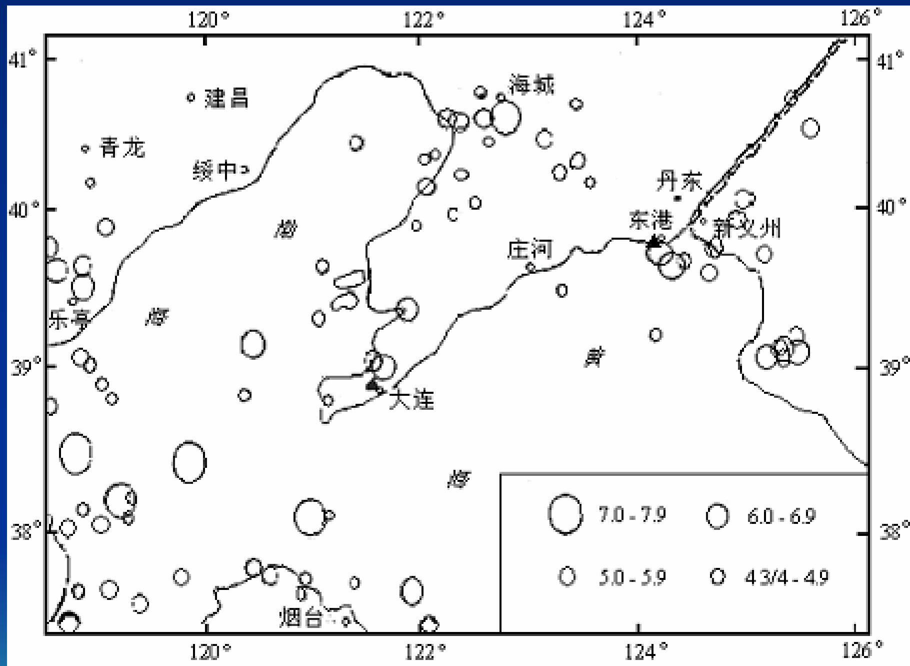
Earthquake distribution in research region



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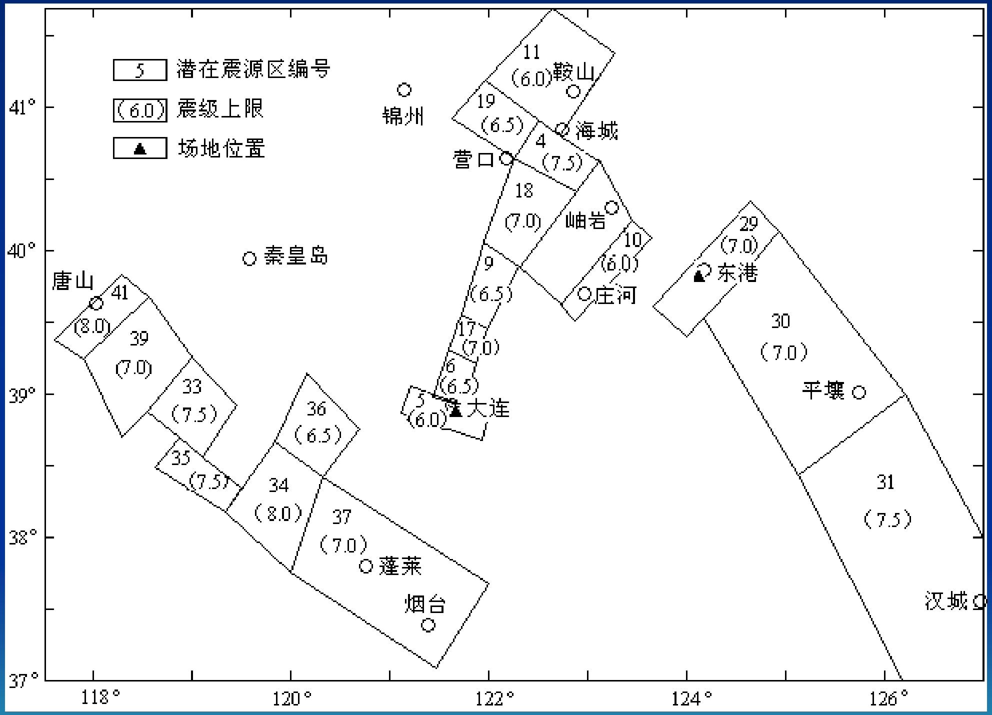
PSA in the region of Liaoning province



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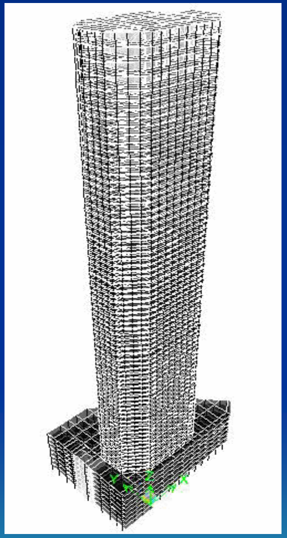
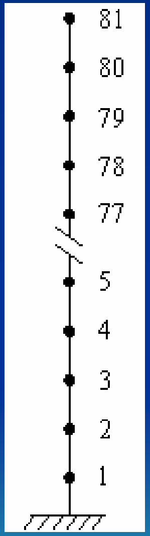
- The high-rise building we take as example is located in the center of Dalian, in northeast of China, which has one basement and 80 stories with the height of 339m, the total construction area is 290,000m^2.





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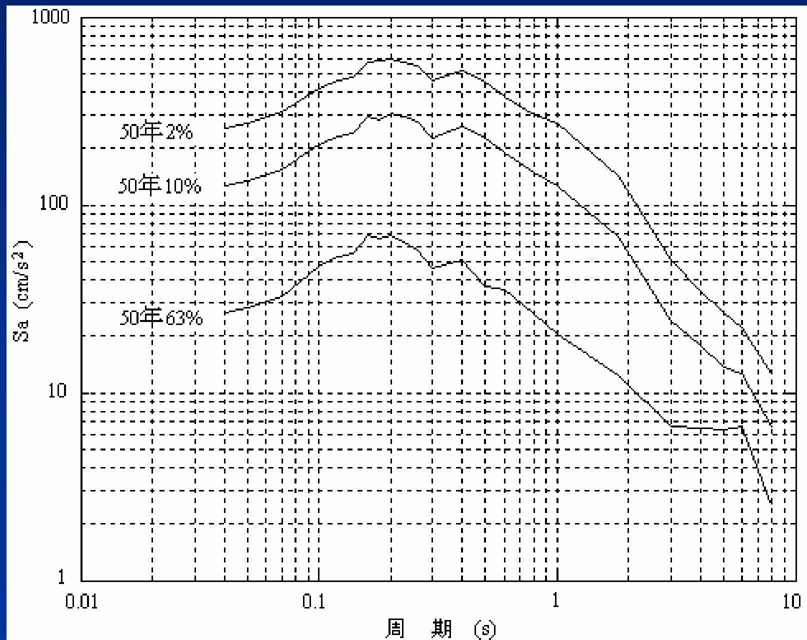
- PSHA result at the site



50a	63%	10%	2%
PGA	24.94 cm/s^2	118.78 cm/s^2	241.29 cm/s^2
EPA	22.19 cm/s^2	113.07 cm/s^2	225.87 cm/s^2

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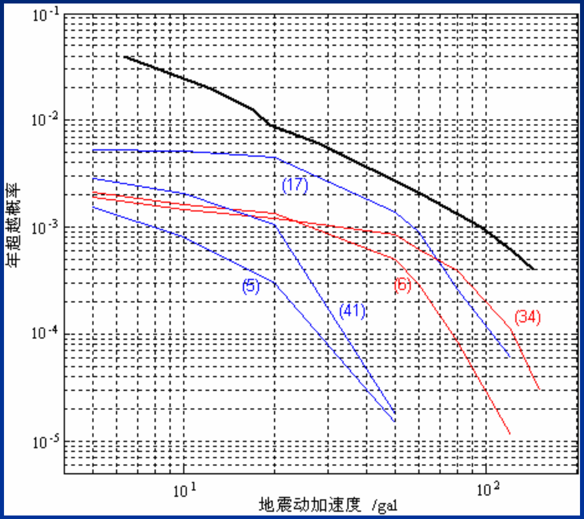
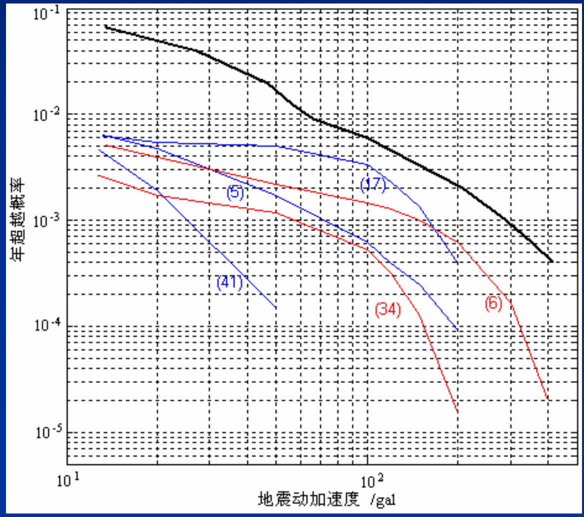
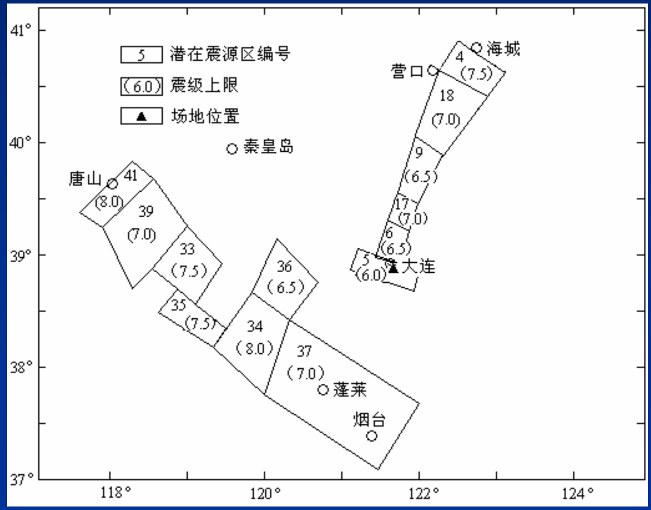
- Contribution of main PSA







T=1.8s

T=0.1s

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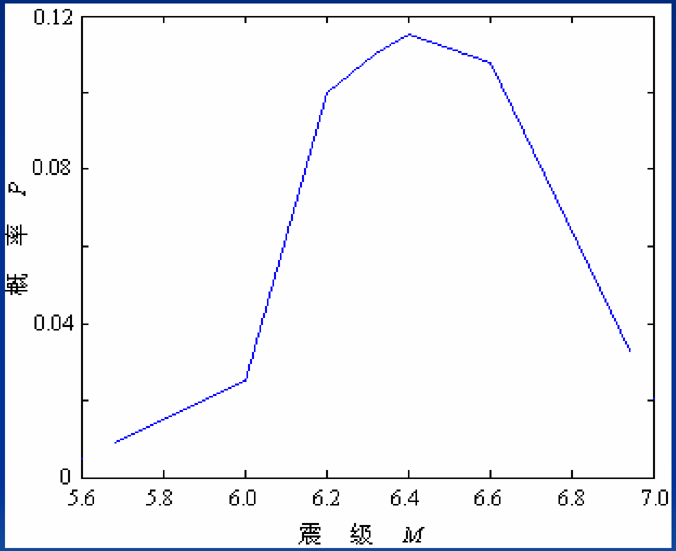
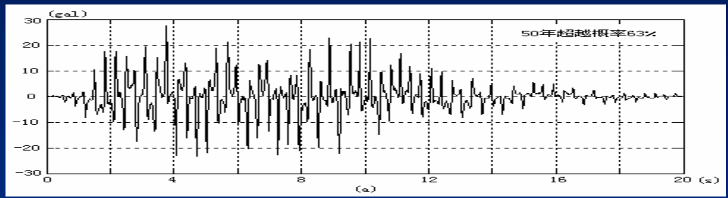
- 50a, 63% exceeding probability(T=1.8s)

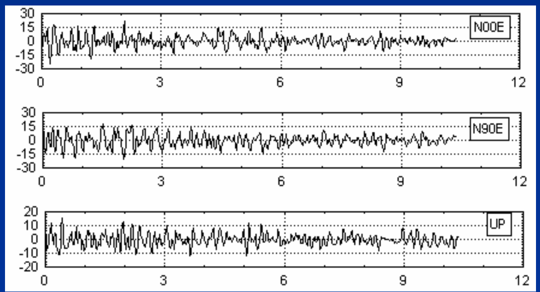


magnitude contribution

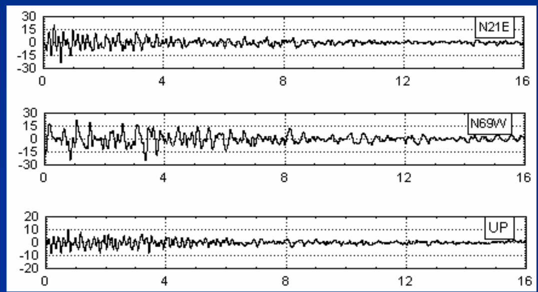
50a, 63%



Simulated accelerogram
（M6.4，R=62KM）



1971/02/09vSAN FERNANDO
（M6.5，R=70KM）



1970/09/12/ LYTLE CREEK
（M5.4，R=108KM）

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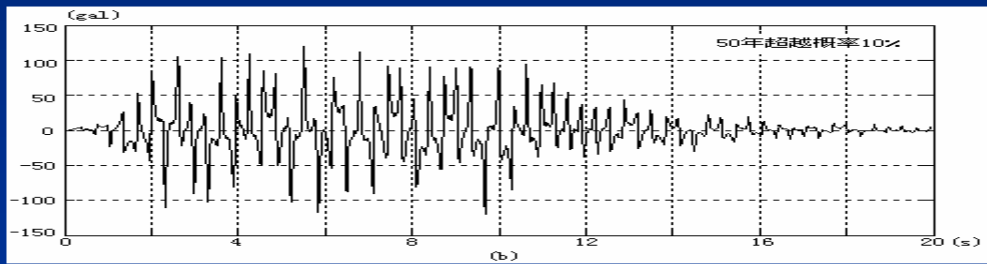
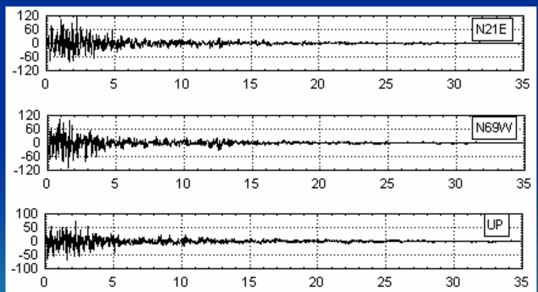
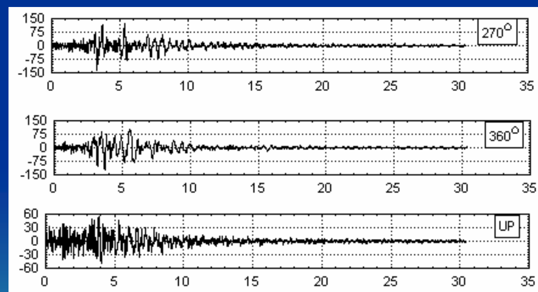
50a, P=10％

M=6.7, R=51km;







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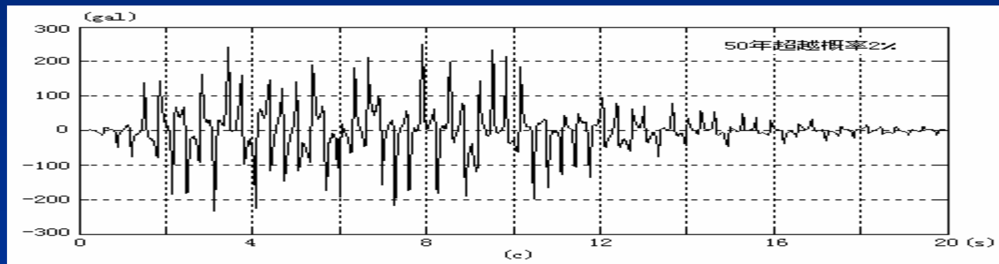
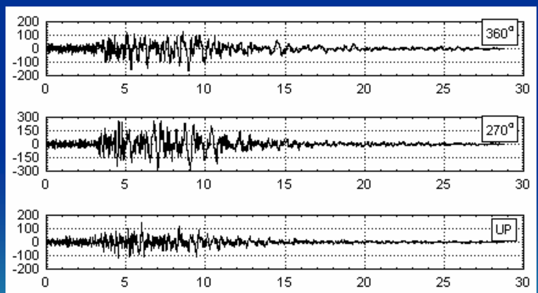
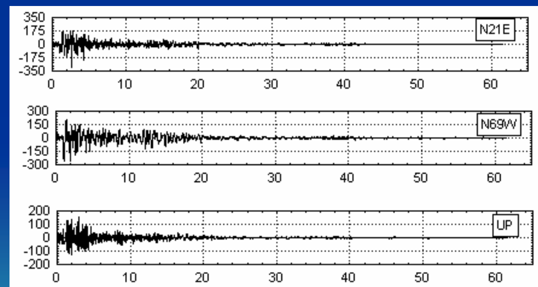
50a, P=2%

M=7.6, *R*=122km







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Brief summary

- Design earthquakes should be selected on structural characters;
- Accelerogram from previous earthquakes could be utilized for structural response analysis, but should be chosen based on regional practical earthquake environment;
- Other methods could be also used to simulate strong ground motions, depending on earthquake scenarios.

Thank you!