Paleoseismic Investigations for Determining the Design Ground Motions for Nuclear Power Plants

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Renewed Interest in Nuclear Power in the US

A New Era?
What a comeback in nuclear energy could mean for engineering

(January 2006)
At least 26 new commercial nuclear reactors at least 16 different sites in at least 12 different states
Percent Cost of a Nuclear Plant vs. Earthquake Ground Acceleration

(Stevenson 2003)
Review of Earthquake Geology
and
Engineering Seismology
Geology of Earthquakes

Earthquakes in Stable Continental Regions???
Geology of Earthquakes in Stable Continental Crust

Johnston and Kanter (1990)
Geology of Earthquakes in Stable Continental Crust

Johnston and Kanter (1990)
Reelfoot Rift
Gutenberg-Richter Magnitude Recurrence Relationship (b-line)

Adapted from Schwartz and Coppersmith (1984)
Paleoliquefaction Features -- Secondary Evidence
Review of Liquefaction Phenomenon

GRAVITY LOAD

U = U_{hs}

BEFORE LIQUEFACTION
Review of Liquefaction Phenomenon

$U = U_{hs} + U_{xs} = \sigma_v$

GRAVITY LOAD

DURING LIQUEFACTION
Review of Liquefaction Phenomenon

GRAVITY LOAD

U = U_{hs}

POST DENSIFICATION
Review of Liquefaction Phenomenon

Olson et al. (2007)
Review of Liquefaction Phenomenon

Stratum $H_1$

Nonliquefiable layer of low permeability

Stratum $H_2$

Liquefied sand layer

Sand Boil (or Blow)

Water flow path

Obermeier (1996)
Geologic Evidence of Earthquakes - Liquefaction

1964 Niigata, Japan (Steinbrugge Collection)

Crater formation & Spreading of Sand at Ten-Mile Hill
1886 Charleston Earthquake (from Dutton 1889)
Review of “Simplified” Liquefaction Evaluation Procedure

\[ CSR_{M7.5} = 0.65 \frac{a_{\max}}{g} \frac{\sigma_v}{\sigma_{v_o}} \frac{r_d}{MSF} \]

amplitude duration
Review of “Simplified” Liquefaction Evaluation Procedure

MSF Proposed by Various Investigators

- Seed and Idriss, (1982)
- Idriss
- Ambraseys (1988)
- Arango (1996)
- Andrus and Stokoe
- Youd and Noble, PL<20%
- Youd and Noble, PL<32%
- Youd and Noble, PL<50%

Earthquake Magnitude, $M$

(NCEER 1997)
Factor of Safety Against Liquefaction:

\[ FS = \frac{CRR}{CSR_{M7.5}} \]
Evidence of Large Paleoeearthquakes in the Wabash Valley
Paleoliquefaction in the Wabash Valley

(Obermeier 1998)
Paleoliquefaction in the Wabash Valley

(Obermeier 1998)
Paleoliquefaction in the Wabash Valley

(Obermeier 1998)
Paleoliquefaction in the Wabash Valley

(Obermeier 1998)
Simplified Liquefaction Evaluation Procedure

\[ \text{FS} = \frac{\text{CRR}}{\text{CSR}_{M7.5}} \]

\[ \text{CSR}_{M7.5} = \text{CSR} \]

\[ N_{1,60cs} \]

Liquefaction

No Liquefaction
Back Analyses (simplified procedure)

\[ FS = \frac{CRR}{CSR_{M7.5}} = 1 \]

\[ a_{\text{max}} = CRR \cdot MSF \cdot \frac{g \cdot \sigma'_{V_o}}{0.65 \cdot \sigma_v \cdot r_d} \]

- \( a_{\text{max}} \) — M combinations requisite to induce liquefaction: \( FS < 1 \)
- \( a_{\text{max}} \) — M combinations insufficient to induce liquefaction: \( FS > 1 \)
Back Analyses (simplified procedure)

\[ FS = \frac{CRR}{CSR_{M7.5}} = 1 \]

\[ a_{\text{max}} = CRR \times MSF \times \frac{g}{0.65 \sigma_v r_d} \]
Paleoliquefaction Features Associated with the Vincennes Event

- re-analyzed as part of this study
- maximum dike width

- ≥ 0.5 m
- 0.30-0.49 m
- 0.15-0.29 m
- 0.05-0.14 m
- < 0.05 m

Green et al. (2005)
Regional Integration of Data

Wabash Valley Seismic Zone

Severity of Liq.

- marginal
- moderate
- severe

- high
- intermediate
- low

Green et al. (2005)
New Madrid Seismic Zone

Seismicity 1925–1995 (Declustered)

B-value = 0.8
(not fit to seismicity)

Paleoliquefaction
Mean Rate:
0.00201/yr

Cramer (2001)
The renewed interest in nuclear power will require the accurate quantification of the earthquake hazard.

In the low-to-moderate seismic zones, paleoliquefaction studies have proven to be a valuable tool in determining the recurrence time of moderate-to-large earthquakes.
The End!!
References:


Steinbrugge Collection: http://nisee.berkeley.edu/visual_resources/steinbrugge_collection.html