The Earthquake Hazard in Kentucky: the Problems, Research, Current Assessment, and On-line Seismic Readings from the KSSMN

John Kiefer and Zhenming Wang
Geologic Hazards Section
Kentucky Geological Survey

*Geohazards in Transportation* Symposium, August 3, 2005
Problems

• Is the seismic hazard assessment for KY controversial?

• The NEHRP seismic hazard and design maps
  – The NEHRP seismic hazard maps (USGS)
    • The 1996 national seismic hazard maps
    • The 2002 national seismic hazard maps
  – The NEHRP seismic design (mitigation) maps (FEMA)
    • The Building Seismic Safety Council (BSSC) – a group of engineers, seismologists, and others
    • Become base maps for seismic safety regulations and designs for
      – The Federal agencies: FEMA, DOE, USACE, EPA, FHWA, and others
      – The State agencies: KY-EPA, Dept. of Housing, Economic Development
      – Other private organizations
  • The International Building Code (IBC) and Residential Code (IRC)
• Question: does it make sense if
  – You have to pay more for mitigating seismic hazards in Paducah than in San Francisco or Los Angeles?
Development Issues

• Mr. David Mast (a staff member from KY congressman Ed Whitfield’s office): Why can’t I build a two-story house in Paducah?
• SEAOK protests that it is impossible to construct residential structures in westernmost Kentucky without enlisting a seismic design professional (IRC 2000).
• DOE cannot get a permit from EPA to build a landfill at PGDP for clean-up.
• One of the main reasons that Kentucky lost the centrifuge facility ($2B).
Summary on Seismic Hazard

• There is no question: there are seismic hazards in Ky., WK in particular.
• The question is: what level of the seismic hazard.
• Current assessment (USGS) is too high in WK
  – It does not reflect the state-of-knowledge
• Seismic hazard assessment is a difficult job. Our focus are:
  – How to characterize it
    • Methodologies
    • Input parameters (source, frequency, and attenuation)
  – How to communicate it??
# Problems

- **Answer:** NO! (geology and seismology)

<table>
<thead>
<tr>
<th></th>
<th>California</th>
<th>West Kentucky</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Probability</strong></td>
<td>(Deterministic)</td>
<td>2 % ~ 5% in 50 years</td>
</tr>
<tr>
<td><strong>Design (0.2 s)</strong></td>
<td>&lt;=1.0g (UBC-97)</td>
<td>&lt;=0.7g PGA (CALTRAN)</td>
</tr>
<tr>
<td></td>
<td>&gt;1.0g (IBC-2000)</td>
<td>&gt;1.0g PGA (Bridge)</td>
</tr>
<tr>
<td><strong>Geology</strong></td>
<td>San Andreas fault</td>
<td>New Madrid faults</td>
</tr>
<tr>
<td></td>
<td>&gt;20 mm/y well defined</td>
<td>&lt;2 mm/y poorly defined</td>
</tr>
<tr>
<td><strong>Seismology</strong></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>M7.0-8.0: ~100 y</td>
<td>M7.0-8.0: ~500 y</td>
</tr>
<tr>
<td></td>
<td>M6.0-7.0: ~20-50 y</td>
<td>M6.0-7.0: ?</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>Very well</td>
<td>?</td>
</tr>
</tbody>
</table>
Problems

(Hough et al., 2000)

Very limited data points!

<table>
<thead>
<tr>
<th>INTENSITY</th>
<th>EFFECTS</th>
<th>AVE. PEAK ACCELERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI</td>
<td>Strong 0.06–0.07g</td>
<td>Felt by all. Damage slight.</td>
</tr>
<tr>
<td>VII</td>
<td>Very Strong 0.10–0.15g</td>
<td>Everybody runs outdoors. Considerable damage to poorly designed buildings.</td>
</tr>
<tr>
<td>VIII</td>
<td>Destructive 0.25–0.30g</td>
<td>Considerable damage to ordinary buildings.</td>
</tr>
<tr>
<td>IX</td>
<td>Ruinous 0.50–0.55g</td>
<td>Great damage to ordinary buildings</td>
</tr>
<tr>
<td>X</td>
<td>Disastrous &gt;0.60g</td>
<td>Many buildings destroyed.</td>
</tr>
<tr>
<td>XI</td>
<td>Disastrous</td>
<td>Few, if any, structures remain standing</td>
</tr>
</tbody>
</table>

(Modified Mercalli Intensity Scale, Simplified from Bolt, 1990)
KGS-DGS Research

- Seismic hazard mitigation policies, such as building codes, are complicated
  - Sciences (seismology and geology)
  - Engineering
  - Economic
  - Political
  - Societal

- Our focus: Sciences (geology and seismology) – bases
  - What do we know (data at UK – Ron Street)?
  - What information can we provide (how large uncertainty)?
  - How should we communicate with decision makers (understandable)?

- Projects (~$300K/year combined)
  - USGS NEHRP
  - DOE
  - NSF: US - China Collaborative Research ($2.5M proposal)
KGS-DGS Research

• Scientific Research
  – Detailed analyses on the USGS seismic hazard maps
    • Methodology (PSHA)
    • Input database used in the national hazard mapping
    • Products (what they are)
  – Enhancing the Kentucky Seismic and Strong Motion Network
  – Neo-tectonics – geophysical investigations
  – Earthquake ground motion and its attenuation

• Communication
  – Elected officials (Governor, US and State Representatives)
  – Governmental agencies:
    • USGS, FEMA, DOE, NRC, USACE, EPA
    • KY-EPA, Dept. of Housing, Economic Development
  – Professional communities: SSA, EERI, AGU, AEG, GSA
  – Non-governmental organization: BSSC, SEAOK, CUSEC
1. Journal papers
2. KGS special publications
3. Comments
4. Abstracts
5. Presentations

(Some seismic hazards related publications in last three years)
Problems:
1. many choices
2. why one point is better than the others
3. what is the physical meaning of the point chosen

Probabilistic Seismic Hazard Analysis (PSHA)
Seismicity in Southern California

Seismicity in New Madrid Seismic Zone (Characteristic Earthquake)
Ground motion attenuation comparison
The first recordings from a vertical strong motion array in the central and eastern US (-Ron Street)
October 21, 2004, earthquake (Md2.5)

KGS-DGS Research

Vertical Accelerometer
Array VSAS

Free-Field Accelerometer
FBA-23

Geotechnical Hole

Deep Drill Hole

Top of Paleocene, 243m
(not to scale)

Acceleration (cm/s/s)

Time (sec)
KGS-DGS Research

NEHRP Soil Classification

(Street et al., 2001, Engineering Geology, 62:123-135)
## Site Class Definitions

### Table 1615.1.1
**Site Class Definitions**

<table>
<thead>
<tr>
<th>SITE CLASS</th>
<th>SOIL PROFILE NAME</th>
<th>Average Properties in Top 100 feet, as per Section 1615.1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Hard rock</td>
<td>Soil shear wave velocity, $\bar{v}_s$ (ft/s) Not applicable</td>
</tr>
<tr>
<td>B</td>
<td>Rock</td>
<td>2,500 &lt; $\bar{v}_s$ ≤ 5,000 Not applicable</td>
</tr>
<tr>
<td>C</td>
<td>Very dense soil and soft rock</td>
<td>1,200 &lt; $\bar{v}_s$ ≤ 2,500 $\overline{N}$ &gt; 50</td>
</tr>
<tr>
<td>D</td>
<td>Stiff soil profile</td>
<td>600 ≤ $\bar{v}_s$ ≤ 1,200 15 ≤ $\overline{N}$ ≤ 50</td>
</tr>
<tr>
<td>E</td>
<td>Soft soil profile</td>
<td>$\bar{v}_s$ &lt; 600 $\overline{N}$ &lt; 15</td>
</tr>
<tr>
<td>E</td>
<td>—</td>
<td>Any profile with more than 10 feet of soil having the following characteristics:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Plasticity index $PI$ &gt; 20;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Moisture content $w$ ≥ 40%, and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Undrained shear strength $\bar{s}_u$ &lt; 500 psf</td>
</tr>
<tr>
<td>F</td>
<td>—</td>
<td>Any profile containing soils having one or more of the following characteristics:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Peats and/or highly organic clays ($H$ &gt; 10 feet of peat and/or highly organic clay where $H$ = thickness of soil)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Very high plasticity clays ($H$ &gt; 25 feet with plasticity index $PI$ &gt; 75)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Very thick soft/medium stiff clays ($H$ &gt; 120 ft)</td>
</tr>
</tbody>
</table>

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m², 1 pound per square foot = 0.0479 kPa.
Current Assessment

2% PE in 50 years = 2,500 years recurrence period
10% PE in 50 years = 500 years recurrence period

http://eqhazmaps.usgs.gov/
On-line seismic readings

Click on Station to see current Seismic Recordings

Kentucky Seismic and Strong-Motion Network

http://www.uky.edu/KGS/geologichazards/equake3.htm
On-line seismic readings

LEXINGTON
(BHKY)
Latitude: 38d 22m 06.00 N
Longitude: 84d 30m 18.00 W

Seismic Stations - Microsoft Internet Explorer
Address: http://www.uky.edu/KGS/geologichazards/seismic.gifs.html
On-line seismic readings

- Kentucky Seismic Network Serves
  - Monitoring/locating earthquakes occurring in and around Kentucky
  - Differentiating earthquake from mine blasts
  - Providing information on earthquakes
On-line Seismic Readings

December 26, 2004, Sumatra Earthquake (M9+)

March 21, 2005, Salta, Argentina, Earthquakes (M6.9, 6.0)

February 10, 2005, Arkansas Earthquakes (M4.1)
On-line seismic readings
On-line seismic readings

September 23, 2005, earthquake (mb,Lg2.0)

\[ X = \frac{(T_s - T_p)}{\left(\frac{1}{V_s} - \frac{1}{V_p}\right)} \approx (T_s - T_p) \times 8.0 \]