PROBABILISTIC ESTIMATION OF SEISMIC HAZARD FOR MONGOLIA AND ULAANBAATAR CITY.

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Seismic hazard assessment?

The probability of occurrence of a certain level of shaking in a specified time interval at a given location.
The Eurasia-India collision Front (red) and the main induced structures in central Asia
Figure 4. GPS-derived velocities with respect to Eurasia. Ellipses are 95% confidence. Numbers by the site names are velocities with respect to Eurasia in mm yr⁻¹.

CALAIS ET AL 2003: GPS MEASUREMENTS IN MONGOLIA
Seismicity around Ulaanbaatar (extract from the map “One century of seismicity in Mongolia (1900-2000)”) and focal mechanism of Deren earthquake, 24/09/1998; Mw=5.3.
Length 30 km, vertical cumulated displacement = 6m => Mw = 6.5 to 7?
- 3 to 4 events of magnitude about $M_w = 7$ built the scarp
- The last event took place about 1000 years ago (Thermoluminescence dating)
- The earthquake of the 24/9/1998 is not directly related to this active scarp
Impact of the seismotectonic model

475 years return period Attenuation law Huo & Hu 1992 used by the GSHAP

GLOBAL SEISMIC HAZARD MAP 1999
Produced by the Global Seismic Hazard Assessment Program (GSHAP), a demonstration project of the UN/International Decade of Natural Disaster Reduction, conducted by the International Lithosphere Program. Global map assembled by D. Giardini, G. Grünthal, K. Shedlock, and P. Zhang

Detailed seismotectonic Model

Return period for M=8 ⇒ 3500 years (Ritz et al, 1995 and 2003)
Regional attenuation?

Site effect?
- Geometry
- Geology

Potential seismic source?
- Location
- Magnitude
- Depth
- Probability
- Return period
Regional attenuation of the PGA (Peak Ground Acceleration) with distance

Fukushima et al (2003) attenuation law (for 12 km depth) compared to observed Horizontal PGA in Mongolia

Over-estimation at short distance for large EQ
Impact of the attenuation law = factor of more than 2 on the results
SITE EFFECT AT
ULAANBAATAR
Thickness of sedimentary deposits and location of measurements

- Reference point on rock
- 0-10 m
- 10-30 m
- 30-50 m
- 50-80 m
- 80-120 m
- Neogen clay

- Noise recording during an hour
- Continuous recording during a week with 3 to 4 earthquakes recorded per site
Site/reference spectral ratio for two sites on sediments and associated recorded signals.

Amplified signal by the sedimentary basin

Event 01, ML=3.0, dist=531 km from reference point, az=63

Earthquake - 22/03/2001 23:01:47 44.87 100.65 ML=4.1 dist. = 580 km, az. = 235
Example of site effect recorded at the point A in Ulaanbaatar Basin

Using H/V and Site to Reference technics on weak motion, we observe stable amplified frequencies but unstable amplification factors.

=> Microzoning of Ulaanbaatar in frequency

Complementary research => 2006 to 2009 PhD in France (Researcher of RCAG under direction of Dr. Schlupp)
Active fault model and soft sediment location (potential amplification of ground motion)

- Amplification zones
  - 7 - 7.4
  - 7.5 - 7.9
  - 8 - 8.5

- Site effect at Ulaanbaatar

- Amplification zones
  - 0 - 2 Hz
  - 2 - 4 Hz
  - 4 - 8 Hz
  - 8 - 15 Hz
Process to estimate the peak ground acceleration (PGA) expected at a site for a giving return period or probability.
Results for the Probabilistic Seismic Hazard Assessment at Ulaanbaatar
<table>
<thead>
<tr>
<th>Return period (years)</th>
<th>PGA at rock (g)</th>
<th>Intensity at rock (MSK)</th>
<th>Intensity at zone 0-2 Hz (MSK)</th>
<th>Intensity at zone 2-4 Hz (MSK)</th>
<th>Intensity at zone 4-8 Hz (MSK)</th>
<th>Intensity at zone 8-15 Hz (MSK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>475</td>
<td>0.05</td>
<td>VII</td>
<td>VIII</td>
<td>VIII</td>
<td>VIII</td>
<td>VII</td>
</tr>
<tr>
<td>975</td>
<td>0.06</td>
<td>VII</td>
<td>VIII-IX</td>
<td>VIII-IX</td>
<td>VIII-IX</td>
<td>VII-VIII</td>
</tr>
<tr>
<td>1975</td>
<td>0.07</td>
<td>VII</td>
<td>IX</td>
<td>IX</td>
<td>IX</td>
<td>VIII</td>
</tr>
<tr>
<td>5000</td>
<td>0.08</td>
<td>VII</td>
<td>IX</td>
<td>IX</td>
<td>IX</td>
<td>VIII</td>
</tr>
<tr>
<td>10000</td>
<td>0.09 - 0.12</td>
<td>VII-VIII</td>
<td>IX-X</td>
<td>IX-X</td>
<td>IX-X</td>
<td>VIII-IX</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.62</td>
<td>X</td>
<td>XI+</td>
<td>XI+</td>
<td>XI+</td>
<td>XI+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dominant contribution on the return period of (years)</th>
<th>Event type</th>
<th>Distance in km from Ulaanbaatar Center</th>
<th>Magnitude</th>
<th>PGA at Ulaanbaatar Center at rock (Fukushima et al. 2003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>475 years</td>
<td>From seismotectonic zone of Ulaanbaatar</td>
<td>12</td>
<td>4.1</td>
<td>0.06 g</td>
</tr>
<tr>
<td>975 years</td>
<td>From seismotectonic zone of Ulaanbaatar</td>
<td>12</td>
<td>4.5</td>
<td>0.08 g</td>
</tr>
<tr>
<td>1975 years</td>
<td>From seismotectonic zone of Ulaanbaatar</td>
<td>12</td>
<td>5.3</td>
<td>0.13 g</td>
</tr>
<tr>
<td>10000 years</td>
<td>Event breaking the whole Hustain fault</td>
<td>47</td>
<td>7.5</td>
<td>0.12 g</td>
</tr>
</tbody>
</table>
MICROZONING MAP OF AMPLIFIED FREQUENCIES FOR ULAANBAATAR DEDUCED FROM THE SITE EFFECT MEASUREMENTS AND ANALYSIS

ZONATION OF AMPLIFIED FREQUENCY

- <2 Hz
- 2-4 Hz
- 2-4 Hz and 4-8 Hz
- 4-8 Hz
- > 8 Hz
Seismic activity of the Sonsoglon & Songino area, west part of Ulaanbaatar
<table>
<thead>
<tr>
<th>Event</th>
<th>Ms</th>
<th>Distance to the fault</th>
<th>PGA at rock (g)</th>
<th>Related intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1: maximum earthquake on Khustain fault</td>
<td>7.5</td>
<td>47 km</td>
<td>0.12</td>
<td>VII-VIII</td>
</tr>
<tr>
<td>Scenario 2: max earthquake in the seismotectonic zone of Ulaanbaatar or on the Songino-Sonsoglon active area considering a site at the surface</td>
<td>6.5</td>
<td>0 km</td>
<td>0.62</td>
<td>X</td>
</tr>
<tr>
<td>Scenario 3: max earthquake on the Songino-Sonsoglon active area observed at Ulaanbaatar Center</td>
<td>6.5</td>
<td>10 km</td>
<td>0.25</td>
<td>VIII-IX</td>
</tr>
<tr>
<td>Scenario 4: max earthquake on the Songino-Sonsoglon active area observed at the east part of Ulaanbaatar</td>
<td>6.5</td>
<td>20 km</td>
<td>0.15</td>
<td>VIII</td>
</tr>
</tbody>
</table>

0.62g is classified as “violent to extreme perceived shaking” and with “very heavy potential damage” for a modern city (Intensity of X in MSK scale).
Preliminarily results for the Probabilistic Seismic Hazard Assessment in Mongolia
475 years = a probability of exceedence of 10% for an exposure time of 50 years

Fukushima attenuation law
475-year return period
1975 years = a probability of exceedence of 2.5% for an exposure time of 50 years

Fukushima attenuation law
2000-year return period
10 000 years = a probability of exceedence of 0.5% for an exposure time of 50 years

Fukushima attenuation law
10000-year return period
Conclusions

=> The seismic hazard assessment of Mongolia and Ulaanbaatar (RCAG, DASE, EOST research collaboration) is built on an active fault model, on an homogeneous seismic catalog (reviewed in 2002), on an attenuation law that fits with the available data and on a specific study of site effect for Ulaanbaatar.

=> It shows the importance of the input data (importance to continue collecting them), as the characteristics of the deformation (GPS velocity, active fault which did not ruptured recently, return period of large events ...).

=> It shows the necessity to measure the local attenuation of waves and to concentrate studies on potential active structures near of the main cities (Songino)

=> All these results have the aim to estimate the level of hazard and the parameters of the ground Shaking. Do to this new knowledge, the topic on which the future research has to be concentrated are precised.
To reduce the impact of potential earthquake and to use at best the hazard knowledge and studies, it is important to promote close relation and collaboration between scientific, experts, building designers and emergency organizations.