Seismic Hazard Studies in Vietnam

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OUTLINE

- Seismic Hazard in Vietnam
- Seismic network
- Attenuation Law
- SHA History
- Seismic Hazard Mapping in Vietnam
- Conclusion
SEISMIC HAZARD IN VIETNAM

- A comprehensive catalog compiled for 1900 onwards shows a high seismic activity in the northern part (inland) and in the central part (offshore) of the country.
- The largest earthquakes in country: 3
  - 1 historical (in the 14th century)
  - 2 recorded:
    - Dien Bien 1935 (M=6.7) and Tuan Giao 1983 (M=6.8)
- Offshore volcanic earthquake 1923 (M=6.1).

Seismotectonic map of Vietnam and adjacent sea areas
SEISMIC HAZARD IN VIETNAM

The Tuan Giao earthquake, 1983 (M=6.8)
SEISMIC HAZARD IN VIETNAM

- There is a growing understanding of the active faults in the territory and on continental shelf of Vietnam, which indicates that they may generate as large earthquakes as any that occurred during 20th Century.
SEISMIC NETWORK OF VIETNAM

Present

24 stations (short periods):
North Vietnam: 20
Central Vietnam: 3
South Vietnam: 2
Seismographs: L-4C-1D (8) and L-4C-3D (17)
T=1
SEISMIC NETWORK OF VIETNAM

By 2015

36 broad band stations
North Vietnam: 18
Central Vietnam: 8
South Vietnam: 10

Seismographs: Broadband remote seismic stations

GPS systems

Internet system for data transmission

Data acquisition and processing centre in Hanoi
ATTENUATION LAW

• Ground motion data was not available in Vietnam for a long time.

• The first accelograms within Vietnam were obtained only since the year 2000 during the Dien Bien earthquake of February 19th, 2001 (Ms=5.3).

• Until recently, no local attenuation function had been developed for Vietnam due to the lack of ground motions data. For a long time, seismic hazard assessment for Vietnam has to base on the functions developed by foreign investigators.
ATTENUATION LAW

• In 2011, new attenuation relationships of peak ground acceleration (PGA) and peak ground velocity (PGV) for northern Vietnam developed on the basis of broadband seismic data were published (Le Minh Nguyen et al, 2011, Journal of Asian Earth Sciences). Ground motion data comprises 330 amplitude records by 14 broadband stations from 53 shallow earthquakes occurred in and around northern Vietnam in the period between 01/2006 and 12/2009 with magnitudes between 1.6 and 4.6, focal depths less than 30 km, and epicentral distances less than 500 km:

\[
\log_{10}(\text{PGA}) = -0.987 + 0.7521M_L - \log_{10}(R) - 0.00475R; \\
\log_{10}(\text{PGV}) = -3.244 + 0.9008M_L - \log_{10}(R) - 0.00322R;
\]

where PGA is in cm/s^2, PGV is in cm/s, and R is the epicentral distance in kilometers.

• However, these attenuation relationships have not been used for SHA in Vietnam yet.
Earthquake has been studied in Vietnam since the last 60’s of the 20th Century. The half-century history of earthquake hazard assessment in Vietnam can be divided into two periods, reflecting two different approaches on methodology used: the deterministic and the probabilistic ones.
SHA HISTORY

Deterministic

• 1968-1985
• Parameters estimation using deterministic methods
• Seismic zoning maps: North Vietnam (1968), South Vietnam (1980) and entire country (1985, frequently updated).
• Based on seismotectonic regionalization
• Both seismic shaking zones and seismogenic zones are depicted

Probabilistic

• 1985 - now
• Hazard parameters estimation: Gumbel’s extreme value distributions, maximum likelihood method
• Probabilistic seismic hazard maps: Cornell-McGuire method, EQRISK, CRISIS programs
• Based on seismotectonic regionalization
From the beginning of the 21st century,
The state of the art of SHA now includes the widespread use of sophisticated numerical techniques and super-computers for the deterministic simulation of ground motion and the effects brought about in urban areas by earthquakes of great magnitude.

The 3D models will include faults, the geometry of sedimentary basins and the topography, and other physical characteristics of the system, including the anelastic behavior of rocks, all being required for hazard and risk assessment.

At present the large scale scenario-based SHA is widely used in Vietnam for urban seismic/tsunami risk analysis and loss estimation.
SEISMIC HAZARD MAPPING

The first Seismic zoning maps of Vietnam was compiled in 1985 (Pham Van Thuc and Nguyen Dinh Xuyen (editors), 1985), based on existing seismic zoning schemes of North Vietnam (Rezanov I.A. and Nguyen Khac Mao, 1968) and South Vietnam (Le Minh Triet et al., 1980).

The seismic microzoning maps have been compiled for megacities of Vietnam (Hanoi, Ho Chi Minh city, ...). Frequently updated.
Seismic zoning map of Vietnam 1989 (simplified):
• in terms of MSK-64 Intensity
• based on seismotectonic regionalization
• both seismic shaking zones and seismogenic zones are depicted
• for each seismic source zone, a set of parameters such as expected maximum magnitude $M_{max}$ and average focal depth $h$ are indicated.
The first probabilistic seismic hazard map of Vietnam was compiled in 1993 by Nguyen Hong Phuong. Based on a seismotectonic regionalization of Vietnam, Cornell’s probabilistic method and McGuire’s \textit{EQRISK} program were used for compiling the map in terms of peak ground acceleration.

The PGA maps have been updated afterwards by adding the source zones to take into account the shakings generated from the countries adjacent to Vietnam, and from the South China sea.
In 2006, the anti-seismic design code TCXD-VN 375 2006 was issued by the Ministry of Construction of Vietnam, using a PGA map provided by Institute of Geophysics, VAST.
The most recent Probabilistic Seismic Hazard Maps of Vietnam were compiled in 2010 in a framework of a National Research Project on Earthquake and Tsunami Hazard Assessment for the coastal zones of Vietnam. These are the most comprehensive PGA maps which have ever been compiled for Vietnam up to now.
The seismic source zones were defined on the basis of the known relationship between earthquake manifestation and the geologic structure and the tectonic movement evidence in the study area. A seismic source zone is defined along seismically active fault system by summing all the possible rupture zones caused by maximum earthquakes, which might occur within given zone. In another words, this is the projection of tectonic fault plans counting from the lowest active layer to the Earth's surface.

55 seismic source zones capable of affecting the territory of Vietnam were defined, of which 14 tsunami source zones are located in the sea areas adjacent to Vietnam.
SEISMIC HAZARD MAPPING

Source delineation

GEM Semi-Annual Meeting – Academia Sinica, Taipei, Taiwan, 6 – 8 JUNE, 2012
SEISMIC HAZARD MAPPING

Source delineation
SEISMIC HAZARD MAPING

Parameters estimation

The Maximum Likelihood and Extreme Value methods were used for estimating the earthquake hazard parameters for each seismic source zone.
SEISMIC HAZARD MAPPING

Parameters estimation
### SEISMIC HAZARD MAPING

#### Parameters estimation

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<td>8.4=1.17</td>
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SEISMIC HAZARD MAPPING

Attenuation equation

The Campbell (1997) attenuation equation was used for hazard calculation for Vietnam:

\[
\ln(A_H) = -3.512 + 0.904 M_w - 1.328 \ln\{R_{SEI}^2 + [0.149 \exp(0.647 M_w)]^2 + [1.125 - 0.112 \ln(R_{SEI}) - 0.0957 M_w]F + [0.440 - 0.171 \ln(R_{SEI})] \text{SSR} + [0.405 - 0.222 \ln(R_{SEI})] \text{SHR} + \varepsilon
\]

where \(A_H\) is the peak ground acceleration in gals, \(M_w\) is the moment magnitude, and \(R_{seis}\) is the epicentral distance, \(F\) is the fault type flag, \(\text{SSR}\) and \(\text{SHR}\) are the ground type coefficients and \(\varepsilon\) is the standard deviation of error.
Probabilistic Seismic Hazard Maps

Probabilistic Seismic Hazard Map of Vietnam in terms of Peak Ground Acceleration (% gals), with 10% probability of exceedance in 100 years (975 years return period)
SEISMIC HAZARD MAPING

Scenario-based SHA

A fault-source model was applied to define scenario earthquakes to be used in seismic hazard and risk assessment procedures in Vietnam at two levels: regional and urban.
SEISMIC HAZARD MAPING

Simulation of Tuan Giao earthquake, 1983 (Son La fault, $M_w = 6.8$, $h = 23$ km).
SEISMIC HAZARD MAPPING

Scenario-based SHA

Ba Dinh district, Hanoi city
SEISMIC HAZARD MAPPING

Scenario-based SHA

Ba Dinh district, Hanoi city
SEISMIC HAZARD MAPING

Scenario-based SHA
Ba Dinh district, Hanoi city
Casualties: 2 level, at 2 am
2 level, at 2 pm
2 level, at 5 pm
CONCLUSION

1) Advanced methodology of PSHA/DSHA needed for updating the seismic hazard maps of Vietnam in the future

2) Idea of a “seamless” PSHA/Risk maps for the region

3) Looking forward for collaboration in SHA and Risk Assessment!
Seismic Hazard Studies in Vietnam

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THANK YOU!