Earthquake Hazards: A Brief Analysis of Seismotectonic Activities in Myanmar Region

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Natural Hazards in Myanmar

1-Earthquakes
2-Floods
3-Storms
4-Storm Surges
5-Land Slides
6-Fires
1. Causes and Characteristics

• *Geographically*, a larger part of *Myan* lies in the Sn part of the *Himalaya* & the En margin of the *Indian Ocean*, hence exposed to bigger EQs.

• *Myan* is EQ-prone as it lies in one of the 2 main EQ belts of the world, known as the *Alpide Belt* that starts from the Nn *Mediterranean* in the W, & then extends eastwards through *Turkey, Iran, Afghanistan, the Himalayas*, & *Myanmar* to finally *Indonesia*.

• The seismotectonics of *Myan* is in Figure 1.
Figure 1 - Seismotectonic Map of Myanmar and Surrounding Regions [1900 – 2009]

Active Faults are shown in red lines
EQs in Myanmar have resulted from 2 main sources namely:

1. The continued Subduction (with collision only in the north) of the northward-moving Indian Plate underneath Burma Platelet (which is a part of the Eurasian Plate) at an average rate of 3.5 cm/yr; and

2. The northward movement of the Burma Platelet from a spreading centre in the Andaman Sea at an average rate of 2.5-3.0 cm/yr (Bertrand et al., 1998; Curray, 2005).
Figure 2

Background Cause

[Map showing geological features and fault lines with annotations for Mandalay and Yangon.]
Subduction Zone between Indian Plate and Myanmar Plate lays on the Western part of Bay of Bengal and adjoining Indian Ocean.
Figure 4

Himalayan Main Boundary Thrust

Sunda Megathrust

Motion of Indian Plate

Indo – Australian Plate

55-60 mm/yr

Oblique Motion Of Indo–Australian Plate/Eurasian Plate

Main Boundary Thrust

Modified from Robin Lacassin, IPG Paris, and Wang Yu, 2007
Myanmar Plate (Sliver)
• * Very large over-thrusts along the Wn Fold Belt have resulted from the former movement, & the Sagaing & related faults from the latter movement.

• Intermittent jerks along these major active faults have caused the majority of EQs in Myanmar.

• These Seismotectonic Processes are still going on.
• The occurrence of Intermediate-Focus EQs (focal depth 70-300 km) along the Wn Fold Belt is due to the Subduction.

• Shallow-Focus EQs (focal depth 0-70 km) along the Central Lowlands & En Highlands is mainly due to shallow-depth strike-slip (e.g., Sagaing Fault) and other faulting (Figure 2).

• * Generally, the shallow EQs tend to be more destructive than intermediate ones for the same magnitude.
Intermediate earthquakes occur only in the Western Fold Belt while shallow crustal earthquakes in other parts of Myanmar. The locations of major faults are superimposed on the focal depth zones. (Maung Thein and Tint Lwin Swe, 2006)
* The **major Seismotectonically Important Faults in Myanmar** are . . . . .

1) **Some unnamed major thrust faults in NWn Myanmar,**
2) **Kabaw Fault along the Kabaw Valley in Wn Myanmar,**
3) **Well-known Sagaing Fault, &**
4) **Kyaukkyyan Fault situated W of Naungcho.**
• The well-known and seismologically very active **Sagaing Fault** (Win Swe, 1972 & 1981; Vigny et al., 2003; Soe Thura Tun, 2006) is the most prominent active fault in Myanmar, trending roughly N-S.

• It has been an **originator** of a large proportion of **destructive EQs** in Myanmar.

• This is due to the fact that **many large urban centres** lie on or near this fault.

• In fact, of the **5 major source zones** in Myanmar, **3** lie around this **large & dangerous fault**.
• As shown at Figure 1, it is a right lateral strike-slip fault extending from S of Putao, W of Katha, through Sagaing, along the En flank of Bago Yomas, then through Bago, & finally into the Gulf of Mottama for a total distance of about 1500 km.

• * The EQs generated by sea-floor spreading in the Andaman Sea, however, are mostly small to moderate & shallow-focus.
2 Frequency & Extent of Earthquakes

- As shown in Epicentral Map (Figure 3) and with reference to the seismo-tectonic map (Figure 1), the majority of the EQs in Myan are mainly confined to 3 zones.

- * Active Faults are shown in red lines (Earthquake data: ANSS Catalogue for the period 1950-2008; from other sources for 1912-1949; data are in Richter Magnitude)
Earthquake data: from NEIC for 1964–2004; from other sources for 1912–1963; data are in Richter Magnitude (modified after Tint Lwin Swe, 2006)
* The seismic records show that there have been at least 16 major EQs with Richter Scale (RS) \( \geq 7.0 \) within the territory of Myanmar in the past 170 years.

The frequency with respect to time may be summarized in Table 1.

<table>
<thead>
<tr>
<th>Type of Earthquake</th>
<th>Richter Scale</th>
<th>Frequency</th>
<th>Time Range</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great</td>
<td>( &gt; 8 )</td>
<td>1</td>
<td>1839-2008</td>
<td>Historical record and NEIC</td>
</tr>
<tr>
<td>Major</td>
<td>7-7.9</td>
<td>15</td>
<td>1839-2008</td>
<td>Historical record and NEIC</td>
</tr>
<tr>
<td>Strong</td>
<td>6-6.9</td>
<td>25</td>
<td>1950-2008</td>
<td>ANSS Catalogue</td>
</tr>
<tr>
<td>Moderate</td>
<td>5-5.9</td>
<td>549</td>
<td>1950-2008</td>
<td>ANSS Catalogue</td>
</tr>
</tbody>
</table>
3 Earthquake-Prone Locations

* The **Seismic Zone Map** of Myan is at Figure 5, which is a probable intensity zoning map.

* It is partly a **deterministic map** as past EQ data and spatially correlated peak ground acceleration (PGA) values for some EQs are used.

* The **highest intensity zone** designated for Myan is the **Destructive Zone** (with probable maximum range of ground acceleration 0.4 – 0.5 g), which is equivalent to **Modified Mercalli (MM) Class IX**.
Seismic Zone Map of Myanmar

(modified Maung Thein and Tint Lwin Swe, 2006)
• There are 4 areas in that very vulnerable zone; namely, Bago-Phyu, Mandalay-Sagaing-Tagaung, Putao-Tanaing, and Kalay-Homalin areas.

• Although the latter 2 have major EQ hazards, they may be less vulnerable as are sparsely populated.

• Important cities & towns that lie in Zone IV (Severe Zone, with probable maximum range of ground acceleration 0.3 – 0.4 g) are

• **Yangon** straddles the boundary between **Zone II & Zone III**, with the old and new satellite towns in the **En part** in **Zone III**, and the original City in **Zone II**.
• About 75% of the Myan people are living in the rural areas.

• Most of their dwellings are still non-engineered structures, which are vulnerable to moderate to high intensity EQs.

• The rate of urban growth increases in some large cities like Yangon & Mandalay.

• Due to urbanization the vulnerability increases in cities and the level of disaster from EQ would increase in major cities.

• On the other hand, some large segments of the active faults have not exhibited any significant seismic activity in the past 50 to 75 years, indicating that the faults are apparently locked and stress is accumulating in those segments.
• (e.g., the Sn segment of the Sagaing Fault that is close to Yangon and Bago cities, & the central segment that is close to Mandalay and Sagaing cities).

• This suggests that a national emergency plan for EQs and related disasters is in need, which should also include operating procedure for disaster preparedness and mitigation with strong support of scientific foresight.

• Vulnerable locations of the country can be studied also on seismotectonic map in which seismically active faults are shown in red lines in comparison with earthquake records (Figure 3).
4 Past Earthquake Events in Myanmar

4.1 Historical Earthquakes

4.2 Recent Earthquakes in Myanmar

* Local historic records of tragic events indicate that the Sagaing fault is the principal source of seismic hazards in Myan.

Table 2 summarizes important historical & recent EQs that have occurred in Myan, & a few instances of destruction are illustrated at Figure 3.
Significant Earthquakes

Historic Earthquakes in Bago
868, 875, 1564, 1567, 1582, 1588, 1590, 1757, 1768, 1830, 1839

Historic Earthquakes in AVA Era
1429, 1467, 1501, 1602, 1696, 1762, 1771, 1776, 1830, 1839

Figure 9
<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Magnitude and/or brief description</th>
</tr>
</thead>
<tbody>
<tr>
<td>868</td>
<td>Bago</td>
<td>Shwemawdaw Pagoda fell</td>
</tr>
<tr>
<td>875</td>
<td>Bago</td>
<td>Shwemawdaw Pagoda fell</td>
</tr>
<tr>
<td>1429</td>
<td>Innwa</td>
<td>Fire-stopping enclosure walls fell</td>
</tr>
<tr>
<td>1467</td>
<td>Innwa</td>
<td>Pagodas, solid and hollow, and brick monasteries destroyed</td>
</tr>
<tr>
<td>24 July 1485</td>
<td>Sagaing</td>
<td>3 well-known pagodas fell</td>
</tr>
<tr>
<td>1501</td>
<td>Innwa</td>
<td>Pagodas, etc. fell</td>
</tr>
<tr>
<td>13 Sept. 1564</td>
<td>Bago</td>
<td>Pagodas including Shwemawdaw and Mahazedi fell</td>
</tr>
<tr>
<td>1567</td>
<td>Bago</td>
<td>Kyaikko Pagoda fell</td>
</tr>
<tr>
<td>1582</td>
<td>Bago</td>
<td>Umbrella of Mahazedi Pagoda fell</td>
</tr>
<tr>
<td>9 Feb 1588</td>
<td>Bago</td>
<td>Pagodas, and other buildings fell</td>
</tr>
<tr>
<td>30 Mar 1591</td>
<td>Bago</td>
<td>The Great Incumbent Buddha destroyed</td>
</tr>
<tr>
<td>23 June 1620</td>
<td>Innwa</td>
<td>Ground surface broken, river fishes were killed after quake</td>
</tr>
<tr>
<td>18 Aug. 1637</td>
<td>Innwa</td>
<td>River water flush</td>
</tr>
<tr>
<td>10 Sept. 1646</td>
<td>Innwa</td>
<td></td>
</tr>
<tr>
<td>11 June 1648</td>
<td>Innwa</td>
<td></td>
</tr>
<tr>
<td>1 Sept. 1660</td>
<td>Innwa</td>
<td></td>
</tr>
<tr>
<td>3 April 1690</td>
<td>Innwa</td>
<td></td>
</tr>
<tr>
<td>15 Sept. 1696</td>
<td>Innwa</td>
<td>4 well-known pagodas destroyed</td>
</tr>
<tr>
<td>8 Aug. 1714</td>
<td>Innwa</td>
<td>Pagodas, etc. fell; the water from the river gushed into the city</td>
</tr>
<tr>
<td>4 June 1757</td>
<td>Bago</td>
<td>Shwemawdaw Pagoda damaged</td>
</tr>
<tr>
<td>2 April 1762</td>
<td>Sittwe</td>
<td>M=7 RS; very destructive violent earthquake felt over Bengal, Rakhine up to Calcutta.</td>
</tr>
<tr>
<td>27 Dec 1768</td>
<td>Bago</td>
<td>Ponnyayadana Pagoda fell</td>
</tr>
<tr>
<td>15 July 1771</td>
<td>Innwa</td>
<td></td>
</tr>
<tr>
<td>9 June 1776</td>
<td>Innwa</td>
<td>A well known pagoda fell</td>
</tr>
<tr>
<td>26 Apr 1830</td>
<td>Innwa</td>
<td></td>
</tr>
<tr>
<td>21 Mar 1839</td>
<td>Innwa</td>
<td>Old palace and many buildings demolished;</td>
</tr>
<tr>
<td>Date</td>
<td>Location</td>
<td>Event Description</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>23 Mar 1839</td>
<td>Innwa</td>
<td>Pagodas and city walls fell; ground surface broken; the river's flow was reversed for sometime; Mingun Pagoda shattered; about 300 to 400 persons killed</td>
</tr>
<tr>
<td>6 Feb 1843</td>
<td>Kyaukpyu</td>
<td>Eruption of mud volcanoes at the Rambye (Ramree) Island</td>
</tr>
<tr>
<td>3 Jan 1848</td>
<td>Kyaukpyu</td>
<td>The civil line and other buildings were damaged</td>
</tr>
<tr>
<td>24 Aug 1858</td>
<td>Pyay</td>
<td>Collapsed houses and tops of pagodas at Pyay, Henzada, and Thayetmyo and felt with some damages in Innwa, Sittwe, Kyaukpyu and Yangon</td>
</tr>
<tr>
<td>8 Oct 1888</td>
<td>Bago</td>
<td>Mahazedi Pagoda collapsed</td>
</tr>
<tr>
<td>6 Mar 1913</td>
<td>Bago</td>
<td>Shwemawdaw Pagoda lost its finial</td>
</tr>
<tr>
<td>5 July 1917</td>
<td>Bago</td>
<td>Shwemawdaw Pagoda fell</td>
</tr>
<tr>
<td>10 Sep 1927</td>
<td>Yangon</td>
<td></td>
</tr>
<tr>
<td>17 Dec 1927</td>
<td>Yangon</td>
<td>M=7 RS; extended to Dedaye</td>
</tr>
<tr>
<td>8 Aug 1929</td>
<td>Near Taungoo</td>
<td>Bent railroad tracks, bridges and culverts collapsed, and loaded trucks overturned (Swa Earthquake)</td>
</tr>
<tr>
<td>5 May 1930</td>
<td>Near Khayan</td>
<td>M=7.3 RS, Imax=IX; in a zone trending north-south for 37 km south of Bago (on the Sagaing Fault line); about 500 persons in Bago and about 50 persons in Yangon killed</td>
</tr>
<tr>
<td>3 Dec 1930</td>
<td>Nyaunglebin</td>
<td>M=7.3 RS; railroad tracks twisted (Pyu Earthquake); about 30 persons killed</td>
</tr>
<tr>
<td>27 Jan 1931</td>
<td>East of Indawgyi</td>
<td>M=7.6 RS, Imax=IX; numerous fissures and cracks (Myitkyina Earthquake)</td>
</tr>
<tr>
<td>10 Aug 1931</td>
<td>Pyinmana</td>
<td></td>
</tr>
<tr>
<td>27 Mar 1931</td>
<td>Yangon</td>
<td></td>
</tr>
<tr>
<td>16 May 1931</td>
<td>Yangon</td>
<td></td>
</tr>
<tr>
<td>21 May 1931</td>
<td>Yangon</td>
<td></td>
</tr>
<tr>
<td>12 Sept. 1946</td>
<td>Tagaung</td>
<td>M=7.5 RS</td>
</tr>
<tr>
<td>12 Sept. 1946</td>
<td>Tagaung</td>
<td>M=7.75 RS</td>
</tr>
<tr>
<td>16 July 1956</td>
<td>Sagaing</td>
<td>M=7.0 RS; Several pagodas severely damaged (40 to 50 persons killed)</td>
</tr>
<tr>
<td>8 July 1976</td>
<td>Bagan</td>
<td>M=6.8 RS; Several pagodas in Bagan Ancient City were severely damaged (only 1 person killed)</td>
</tr>
<tr>
<td>22 Sept. 2003</td>
<td>Taungdwingyi</td>
<td>M=6.8; RS Severe damaged to rural houses and religious buildings (7 persons killed)</td>
</tr>
</tbody>
</table>

****most of them along the Sagaing Fault**
• * The epicentres of both the Bago (1930) and the Ava (1839) EQs are sited on the Sagaing Fault Zone, & both areas happened to be located on the flat alluvial plains covered by rice paddy fields.

• Epicenter of the Pyin Oo Lwin (Maymyo) EQ of 1912 seemed to be situated on the Kyaukkyan Fault Zone in the Wn part of the En Highlands, indicating that the Kyaukkyan Fault is also an active structure.

• Figure 4 shows some records of damages of 20th Century EQs in Myan.
Figure 10 - Damages during Past Earthquakes, Myanmar

* Top portion of the Shwemawdaw Pagoda, Bago fell down in the 1917 EQ (5.7.1917). (Top)
* Collapsed primary school during the Taungdwingyi EQ (6.8 RS) & cracks in the dam closed to the epicenter (22.9.2003). (Bottom)
Figure 11 - Tarlay Earthquake (24.3.2012)
Figure 12

Historical Large Earthquakes in and around Myanmar
(ftp://ftppeic.eri.u-tokyo.ac.jp/ERI/DATA/utsu/)

Sato (2003MS)
5 Work on Earthquake Hazards

• 5.1 Seismic Zoning Map

*The Seismic Zone Map of Myan (2005) was prepared by a team led by Dr Maung Thein during 2003 to 2005 with several detail observations & brainstorming.

• Tectonic activities in connection with EQ information from external sources are applied in the development of the map (Maung Thein and Tint Lwin Swe, 2006), deterministically and some intuitively.
Figure 13 – Seismic Zone Map of Myanmar

(modified Maung Thein and Tint Lwin Swe, 2006)
As shown in the Map (Figure 5), 5 Seismic Zones are demarcated and named (from low to high)

1) Zone I (Low Zone),
2) Zone II (Moderate Zone),
3) Zone III (Strong Zone),
4) Zone IV (Severe Zone), and
5) Zone V (Destructive Zone) . . . .

mainly following the nomenclature of the European Macroseismic Scale 1992.

(It should be mentioned that in some countries, there are zones higher than Zone V as used here).
• In near future, the Probabilistic Seismic Hazard Assessment (PSHA) Map, indicating the level of EQ loading of 10% in 50 years is going to be developed.

• During the years of 2005 to 2007, the Myanmar Geosciences Society (MGS), in collaboration with the MEC, sponsored some graduate students of the University of Yangon, for the preparation of preliminary Seismic Micro Zoning Maps for 4 seismically hazardous cities.

• These are Deterministic Maps.
5.2 Earthquake Resistant Design Code

* In development of **Building Code** (Than Myint *et al.*, 2007), the study of that of the other countries like Thailand, India, Indonesia and the **UBC** (Uniform Building Code of United States) are very helpful,

But the background geological setting as well as the surface composition of geologic material, especially technical characteristics and distribution of rock and soil deposits of **Myan**, is quite different from that of other countries.
<table>
<thead>
<tr>
<th>State or Division \ Zone</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bago Division</td>
<td>35</td>
<td>30</td>
<td>20</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Chin State</td>
<td>55</td>
<td>22</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrawaddy Division</td>
<td>95</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kachin State</td>
<td>18</td>
<td>27</td>
<td>32</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Kayah State</td>
<td>98</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kayin State</td>
<td>30</td>
<td>50</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magway Division</td>
<td>15</td>
<td>50</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mandalay Division</td>
<td></td>
<td>45</td>
<td>40</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Mon State</td>
<td>20</td>
<td>70</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rakhine State</td>
<td>15</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagaing Division</td>
<td></td>
<td>10</td>
<td>65</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Shan State</td>
<td>40</td>
<td>40</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanintharyi Division</td>
<td>85</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yangon Division</td>
<td>40</td>
<td>23</td>
<td>20</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>
The seismotectonic research division of the Myanmar Earthquake Committee (MEC) has been studying regional & local EQ, & active faults in Myanmar in collaboration with international researchers.

In this connection, the following issues can be considered for future work & research:
1) Possibility of subduction-related EQ in Rakhine Coast is rather low.

2) Possibility of strong & major EQs along the Sagaing Fault is considerable.

3) Seismic activity of Kyaukkyan - Papun Fault is considerable but the movement along is too much slower than that of the Sagaing Fault.

4) Possibility of moderate to strong EQs in Central Myan Basin, especially along the trans-pressional faults is still high.
Seismic Activities in Myanmar

Figure 14 -
7 Looking Forward

• * Myan is an **EQ-prone country** due to its location in the active Alpide Seismotectonic Belt, the young Alpine-Himalayan-Sumatran orogenic belt.

• **Active Fault Studies** with characterization of EQ response spectrum on engineering structures & design code for buildings are necessary.

• It is suggested that the following activities should be undertaken to **mitigate the seismic risks**.
SEISMOLOGICAL DIVISION

Earthquake Recording
- Yangon 1962
- Mandalay 1966
- Sittway 1971
- Dawei 1985

Strong Motion network 2001
Digital Seismographs 2003
Seismographs obtained JICA, UNESCO, WSSI/OYO, CHINA (Yunnan)

Figure 15 -
Seismic Station Network in Myanmar

- Mandalay
- Yangon
- Dawei
- Sittway
- Pyay
- Monywa
- Myitkyina
- Nyaung O
- Meiktila
- Pathein
- Bago
- Broadband Seismograph instrument
  - sensor: portable very broad band seismeter CTS-1E (China)
  - recorder: EDAS-24 B

2 Digital broadband seismographs are donated by PRC (YSB) in 2003
Organizations involved in Earthquake and Tsunami Disaster Study Group

- Myanmar Engineering Society (Coordinating)
- Myanmar Earthquake Committee
- Quality Control Committee CQHP
- Universities

Figure 17 -
• Continuation, extension, and expansion of the Neotectonic & Active Fault Studies along the Sagaing, Kyaukkyan & Kabaw faults.

• Preparation of the probabilistic seismic zone map of Myanmar (which may be used as a seismic risk map)

• Regular precise GPS measurements along the Sagaing Fault, especially bet Bago & Mandalay.

• Training of some seismologists & EQ engineers, preferably in Japan.

• Upgrading of the existing seismological stations, & then installation of some more modern-type seismological stations in some suitable locations, such as Hpa-an, Pathein, Bago, Pyinmana, Magway, Kalemyo, & Muse.
Thank You All for Your Time and Kind Attention

Professor Maung Maung AYE