Seismic Zonation Map of Bangladesh

Mehedi Ahmed Ansary
Member Steering Committee
Bangladesh National Building Code
&
Bangladesh Earthquake Society (BES)
Department of Civil Engineering BUET
Active Faults Surrounding Bangladesh (Bolt, 1985)

- Dhaka
- Sylhet Fault System
- Tripura Fault System
- Chittagong Fault System
- Bogra Fault System
- Dhubri Fault System
EARTHQUAKE HAZARD ANALYSIS
Earthquake Catalogue

- An earthquake catalogue forms a valuable input for seismic hazard assessment and microzonation studies.
- Critical structures such as nuclear power plants and dams, as well as siting of any new industry, require earthquake data that are accurate, homogeneous and as complete as possible.
- In this study an attempt is made to assess the seismicity of Bangladesh and adjoining region (20-28° north latitude and 86-95° east longitude) during the period 1865-1995 by reviewing instrumental data as well as macroseismic information retrieved from various sources.

1865-2003
<table>
<thead>
<tr>
<th>Date</th>
<th>Lat N°</th>
<th>Long E°</th>
<th>Magnitude M</th>
<th>Mb</th>
<th>Focal depth (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-08-1950</td>
<td>27.5</td>
<td>91.9</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-08-1950</td>
<td>27.9</td>
<td>91.9</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-12-1950</td>
<td>24.4</td>
<td>91.7</td>
<td>6.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>07-04-1951</td>
<td>25.9</td>
<td>90.5</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>07-11-1952</td>
<td>25.5</td>
<td>94.0</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23-02-1954</td>
<td>27.8</td>
<td>91.7</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-04-1955</td>
<td>26.5</td>
<td>90.0</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29-08-1955</td>
<td>26.0</td>
<td>90.5</td>
<td>4.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-09-1955</td>
<td>27.5</td>
<td>90.0</td>
<td>5.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23-11-1955</td>
<td>26.5</td>
<td>90.0</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-12-1955</td>
<td>22.0</td>
<td>92.5</td>
<td>6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-01-1956</td>
<td>23.6</td>
<td>93.5</td>
<td>6.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-03-1956</td>
<td>25.2</td>
<td>90.8</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-06-1956</td>
<td>24.8</td>
<td>90.9</td>
<td>5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-07-1956</td>
<td>22.0</td>
<td>94.0</td>
<td>6.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01-07-1957</td>
<td>24.4</td>
<td>93.8</td>
<td>7.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-12-1957</td>
<td>24.5</td>
<td>93.0</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-02-1958</td>
<td>25.0</td>
<td>90.5</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13-02-1958</td>
<td>27.5</td>
<td>92.0</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22-03-1958</td>
<td>23.5</td>
<td>93.8</td>
<td>6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13-04-1959</td>
<td>22.0</td>
<td>93.3</td>
<td>5.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>07-06-1959</td>
<td>24.0</td>
<td>94.0</td>
<td>5.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>02-11-1959</td>
<td>21.5</td>
<td>92.4</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26-05-1960</td>
<td>27.0</td>
<td>93.0</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29-07-1960</td>
<td>26.5</td>
<td>90.5</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-08-1960</td>
<td>27.0</td>
<td>88.5</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29-09-1961</td>
<td>28.0</td>
<td>87.6</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>06-11-1961</td>
<td>26.7</td>
<td>91.9</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-12-1961</td>
<td>27.0</td>
<td>90.4</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23-10-1962</td>
<td>26.6</td>
<td>93.3</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-08-1964</td>
<td>24.2</td>
<td>94.0</td>
<td>4.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-08-1964</td>
<td>27.6</td>
<td>88.3</td>
<td>5.2</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>30-08-1964</td>
<td>27.1</td>
<td>88.4</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01-09-1964</td>
<td>27.2</td>
<td>92.3</td>
<td>5.7</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>12-01-1965</td>
<td>27.6</td>
<td>88.0</td>
<td>6.1</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>12-01-1965</td>
<td>27.3</td>
<td>87.7</td>
<td>5.3</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>11-04-1965</td>
<td>26.7</td>
<td>92.3</td>
<td>5.1</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>
Revision of Magnitudes

- The idea of revising and unifying existing magnitudes is carried out. The main goal is to produce a file of reliable data that reflect, as homogeneously and completely as possible, the seismicity of the region.

Calculation of surface wave magnitude:

\[ Ms = \log(A/T) + 1.66 \log(\nabla) + 3.3 \]

Use of correlations:

- Surface-wave magnitudes are estimated where possible from semi-empirical relationships between \( M_s \) and \( M_b \).

\[ M_s = a + b \cdot M_b. \]

- Period 1978-1995

\[ Ms = 0.63 + 0.774 \cdot M_b \]

- Period 1964-1977

\[ Ms = 1.27 + 0.68 \cdot M_b \]
Surface-wave magnitudes are also assessed by using the number of stations (NS) that reported it to the ISS or ISC.

\[ Ms = a + b \times \log(\text{NS}) \]

- \( a = 4.21, b = 1.12 \) - period 1900-1963
- \( a = 3.21, b = 0.72 \) - period 1964-1977
- \( a = 2.77, b = 0.81 \) - period 1978-1995

Surface-wave magnitudes are also estimated where possible from semi-empirical relationships between \( M_s \) and Duration Magnitude \( M_d \).

\[ M_s = 0.57 + 1.057 \times M_d \] - period 1993-1995
## New Earthquake Catalogue

<table>
<thead>
<tr>
<th>YR</th>
<th>MNH</th>
<th>DY</th>
<th>H</th>
<th>MIN</th>
<th>S</th>
<th>LON</th>
<th>LAT</th>
<th>DEP</th>
<th>Ms</th>
<th>Mb</th>
<th>Md</th>
<th>M</th>
<th>Mw</th>
<th>ITSC</th>
<th>NS</th>
<th>RMK</th>
<th>LOCATION</th>
<th>REFERENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964 1</td>
<td>22 15 58 47 9360</td>
<td>2240 88 544</td>
<td>610</td>
<td>600</td>
<td>-</td>
<td>153</td>
<td>MR-ID</td>
<td>ROT,ISC,MOS,SHL,USCGS,IS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 2</td>
<td>1 11 28 19 8778</td>
<td>2730 33 442</td>
<td>480</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>NP</td>
<td>ISC,USCGS,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 2</td>
<td>3 3 10 52 9440</td>
<td>2750 30° 449</td>
<td>530</td>
<td>560</td>
<td>-</td>
<td>67</td>
<td>BU</td>
<td>ROT,ISC,MOS,USCGS,IS,TS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 2</td>
<td>18 4 26 34 9430</td>
<td>2500</td>
<td>-</td>
<td>-</td>
<td>540</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>TS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 2</td>
<td>27 15 10 48 8440</td>
<td>2170 102 545</td>
<td>640</td>
<td>650</td>
<td>-</td>
<td>212</td>
<td>Mandalay.MR</td>
<td>ROT,ISC,MOS,SHL,USCGS,IS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 2</td>
<td>27 23 2 42 9330</td>
<td>2720 25 456</td>
<td>500</td>
<td>560</td>
<td>-</td>
<td>52</td>
<td>BU</td>
<td>ROT,ISC,MOS,USCGS,IS,IS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 3</td>
<td>13 3 20 5 9020</td>
<td>2760 52° 473</td>
<td>620</td>
<td>600</td>
<td>-</td>
<td>53</td>
<td>BU</td>
<td>ROT,ISC,MOS,USCGS,IS,IS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 4</td>
<td>15 16 35 58 8800</td>
<td>2170 36° 468</td>
<td>820</td>
<td>560</td>
<td>-</td>
<td>70</td>
<td>Calcutta.ID</td>
<td>ROT,ISC,QUE,MOS,USCGS,SGS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 4</td>
<td>3 3 10 52 9440</td>
<td>2900</td>
<td>-</td>
<td>-</td>
<td>540</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>TS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 4</td>
<td>9 12 33 22 8790</td>
<td>2150 0 390</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>ID</td>
<td>ISC,SHL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 4</td>
<td>13 17 35 58 9400</td>
<td>2300 61 449</td>
<td>520</td>
<td>600</td>
<td>-</td>
<td>108</td>
<td>MR-ID</td>
<td>ROT,ISC,MOS,USCGS,SHL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964 7</td>
<td>12 9 450 2700</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Sagaing.MR</td>
<td>ISC,ISETR</td>
<td></td>
</tr>
<tr>
<td>1965 1</td>
<td>13 10 58 48 9470</td>
<td>2370 117 492</td>
<td>540</td>
<td>600</td>
<td>-</td>
<td>138</td>
<td>MR-ID</td>
<td>ROT,ISC,USCGS,MOS,SHL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 1</td>
<td>17 14 42 54 9418</td>
<td>2432 158 438</td>
<td>480</td>
<td>-</td>
<td>-</td>
<td>24</td>
<td>MR-ID</td>
<td>ISC,USCGS,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 1</td>
<td>30 2 35 8 8830</td>
<td>2760 21 456</td>
<td>510</td>
<td>560</td>
<td>-</td>
<td>78</td>
<td>Sikkim.BU</td>
<td>ROT,ISC,SHL,MOS,USCGS,SGS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 1</td>
<td>30 5 12 32 8852</td>
<td>2790 33 377</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6A</td>
<td>Sikkim.BU</td>
<td>ISC,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 9</td>
<td>1 13 22 37 9230</td>
<td>2720 33 472</td>
<td>550</td>
<td>600</td>
<td>630</td>
<td>-</td>
<td>148</td>
<td>ID-CH</td>
<td>ROT,ISC,SHL,USCGS,IS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 10</td>
<td>4 20 55 38 9440</td>
<td>2600</td>
<td>- 372</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>MR-ID</td>
<td>NDI</td>
<td>ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 10</td>
<td>6 2 55 0 9450</td>
<td>2790 413 422</td>
<td>-450</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>E.ID</td>
<td>ISC,USCGS,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 10</td>
<td>13 10 36 56 9120</td>
<td>2400</td>
<td>- 399</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12</td>
<td>ID-BD</td>
<td>ISC,NDI</td>
<td>ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 21</td>
<td>9370</td>
<td>2800</td>
<td>37</td>
<td>-</td>
<td>590</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>ID-CH</td>
<td>ISC,ISETR</td>
<td></td>
</tr>
<tr>
<td>1965 25</td>
<td>15 40 7 8860</td>
<td>2790 0 434</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>Sikkim</td>
<td>ISC,NDI</td>
<td>ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 25</td>
<td>15 10 24 9446</td>
<td>2118 104 390</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>MR</td>
<td>ISC,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 1</td>
<td>12 13 32 24 8800</td>
<td>2760 23 529</td>
<td>580</td>
<td>650</td>
<td>-</td>
<td>151</td>
<td>NP</td>
<td>ROT,ISC,PEK,QUE,USCGS,SGS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 1</td>
<td>12 13 55 20 8770</td>
<td>2730 33° 454</td>
<td>520</td>
<td>560</td>
<td>-</td>
<td>52</td>
<td>NP</td>
<td>ROT,ISC,PEK,USCGS,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 1</td>
<td>18 8 17 38 9380</td>
<td>2500</td>
<td>-</td>
<td>-</td>
<td>590</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>PAPER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 1</td>
<td>22 2 41 35 9450</td>
<td>2010 76 454</td>
<td>480</td>
<td>560</td>
<td>-</td>
<td>37</td>
<td>MR-CH</td>
<td>ROT,ISC,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 1</td>
<td>18 4 26 34 9430</td>
<td>2500 36 479</td>
<td>540</td>
<td>600</td>
<td>-</td>
<td>122</td>
<td>ID-CH</td>
<td>ROT,ISC,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 2</td>
<td>25 10 34 7 9464</td>
<td>2363 94 471</td>
<td>520</td>
<td>-</td>
<td>-</td>
<td>98</td>
<td>MR-ID</td>
<td>ISC,PEK,USCGS,MOS,SHL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 3</td>
<td>27 20 45 51 8990</td>
<td>2730 33 360</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>BU</td>
<td>ISC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 4</td>
<td>11 22 33 7 9233</td>
<td>2682 70 485</td>
<td>490</td>
<td>510</td>
<td>-</td>
<td>50</td>
<td>E.ID</td>
<td>ISC,USCGS,TS,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 6</td>
<td>1 4 32 45 9490</td>
<td>2020 57 477</td>
<td>520</td>
<td>600</td>
<td>-</td>
<td>124</td>
<td>MR,M-CH</td>
<td>ROT,ISC,GS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 6</td>
<td>18 8 17 38 9380</td>
<td>2500 46 464</td>
<td>520</td>
<td>600</td>
<td>680</td>
<td>-</td>
<td>105</td>
<td>MR-ID,ID-CH (Arakan Y</td>
<td>ROT,ISC,GS,TS,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 7</td>
<td>5 23 41 39 9480</td>
<td>2120 65° 427</td>
<td>440</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>29</td>
<td>MR</td>
<td>ISC,USCGS,NDI,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 8</td>
<td>4 15 27 1 8830</td>
<td>2350</td>
<td>- 343</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>ID-BD</td>
<td>NDI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 9</td>
<td>30 8 48 27 9400</td>
<td>2500</td>
<td>356</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>MR-ID</td>
<td>NDI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 11</td>
<td>6 16 4 59 9170</td>
<td>2710 40 404</td>
<td>430</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>BU</td>
<td>USCGS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 11</td>
<td>6 16 4 59 9160</td>
<td>2720 33</td>
<td>-</td>
<td>-</td>
<td>480</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>BU</td>
<td>USCGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 12</td>
<td>5 22 1 28 9450</td>
<td>2330 13 467</td>
<td>500</td>
<td>560</td>
<td>-</td>
<td>82</td>
<td>MR-ID</td>
<td>ROT,ISC,USCGS,ISETR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965 12</td>
<td>9 20 26 4 9250</td>
<td>2750 22 478</td>
<td>500</td>
<td>560</td>
<td>-</td>
<td>86</td>
<td>ID-CH</td>
<td>ROT,ISC,PEK,USCGS,TS,ISI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Earthquakes in and around Bangladesh (1664-2006)

Ms>7: 17 events
Ms>6: 69 events
Ms>4: 1647 events
Ms>3.5: 3055 events
Ms>3: 4138 events
## Results from Analysis of Completeness for the New Earthquake Catalogue

<table>
<thead>
<tr>
<th>Magnitude Class</th>
<th>Period of Complete Reporting (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3 \leq M &lt; 4$</td>
<td>1964-2006</td>
</tr>
<tr>
<td>$4 \leq M &lt; 5$</td>
<td>1964-2006</td>
</tr>
<tr>
<td>$5 \leq M &lt; 6$</td>
<td>1923-2006</td>
</tr>
<tr>
<td>$6 \leq M &lt; 7$</td>
<td>1927-2006</td>
</tr>
<tr>
<td>$7 \leq M$</td>
<td>1865-2006</td>
</tr>
</tbody>
</table>
Schematic flow of earthquake hazard analysis

1. Location of site
2. Data period (based on completeness)
   - Minimum Magnitude
   - Radius of Area
3. Earthquake catalogue
4. Selection of earthquakes
5. Selection of suitable radius
6. Map of epicenters
7. Magnitude frequency relationship
8. Estimation of a and b parameters
9. Selection of ground motion property to be analyzed (PGA)
10. Expected magnitude for different return period
11. Selection of suitable attenuation law
12. PGA frequency relationship
13. Estimation of a and b parameter
14. Expected PGA for different return periods
15. Expected return period for a fixed PGA value
Seismicity model:

- Available earthquake data
- Recurrence relationship

\[
\log (\nu) = a + b \log(y)
\]

\[
\log(y) = (-\log(T)- a)/b \quad [T=1/\nu]
\]

Attenuation models:

describes the transfer of ground motions from the source to a particular site in the form

\[
\log(PGA) = b_1 + b_2(M_s) - b_3 \log (r) - b_4(r)
\]
Selected Attenuation Law

- Assessment of seismic hazard at any particular site requires an attenuation law for the Peak Ground Acceleration (PGA)

- For Bangladesh no PGA is available due to the lack of seismic devices

- Attenuation law for alluvial soils:
  McGuire (1978) - $PGA = 0.0306e^{0.89M}r^{1.17}e^{-0.2}$ (in g)
  Duggal (1989) - $PGA = 227.3 \times 10^{0.308M(d+30)^{-1.201}}$ (in cm/s²)
SELECTION OF EARTHQUAKES AROUND A SITE

Sensitivity of b-coefficient

PGA versus \( v \) for Sylhet

\[ a = 1.92, \quad b = -1.72 \]
Study region showing the grid points
Seismic hazard of Bangladesh based on Duggal’s (1989) attenuation law

$T = 200$ years
(Unit: cm/s/s)

$T = 475$ years
(Unit: cm/s/s)

22% poe, $t$-50 yr

10% poe, $t$-50 yr
After Noor, Yasin & Ansary (2005)

- Grid interval of 0.3 degree are used
- Uniform probability distributions are assigned to each source zone implying that, earthquakes are equally likely to occur at any point within the source zone
- Seven area sources are assumed
- The sources are so divided that area of each division is limited to 1200 sq km
Seismic hazard of Bangladesh based on Duggal’s (1989) attenuation law

After Noor, Yasin & Ansary (2005)
Seismic Zoning Map of Bangladesh

Seismic Zones
- Zone 3 = 0.25g
- Zone 2 = 0.15g
- Zone 1 = 0.075g

BNBC (1993)

Proposed
Development of Attenuation Law
Magnitude-Intensity & Intensity Attenuation

Data Preparation:
- The average radius of each isoseismal was determined from the radii measured in 16 directions at 22.5° intervals of the compass.
- Isoseismals with no reliable data were disregarded from the regression analysis.
- The description of the 18 earthquakes used in this study is presented in the following table.
Area under study and locations of 28 events
Magnitude-Intensity

Magnitude Intensity Model:

\[ M_{sc} = A_1 + A_2(I_i) + A_3(R_i) + A_4 \log R_i + \sigma P \]

Bangladesh and its surrounding region, which consists of 25 events and 93 pairs \((I_i, D_i)\), is

\[ M_{sc} = -3.336 + 0.549 \sum_{i}^{j} (I_i) + 0.000505 \sum_{i}^{j} (R_i) + 2.964 \sum_{i}^{j} (\log R_i) \pm 0.61P \]
Intensity Attenuation

Intensity-Attenuation Model:

\[ I = B_1 + B_2(M_s) + B_3(R) + B_4 \log R + \sigma P \]

The regression analysis for the whole data set, which consists of 93 \((I_i, D_i)\) pairs corresponding to 25 events, gives the following mean attenuation expression:

\[ I = 6.702 + 1.254(M_s) - 0.0014(R) - 3.966(\log R) \pm 0.92P \]
STRONG MOTION INSTRUMENTATION
Why is Seismic Instrumentation Important?

It helps us to:
- Estimate the probable ground motion.
- Locate earthquakes (epicentre, magnitude, depth).
- Tell how the structure behaves.
- Confirm how to strengthen the structure.
- Improve our design procedures and codes leading to reduced costs but increased safety for future structures.
Jamuna Bridge Seismic Instrumentation Project

- BUET is the Consultant to JMBA, Ministry of Communication, GOB
- Total Project Cost: Tk 4 crore
- Instrumentation has recently been installed (May-July 2003)
- BUET will monitor and analyze seismic data for the next 5 years
Existing Seismic Stations In and Around Bangladesh.

Seismic Stations to be deployed

- JUMBA
- DU-Colombia
- BMD

Symbols:
- ISC-1995
- RRLJ-1998

Countries:
- NEPAL
- BHUTAN
- INDIA
- BANGLADESH
- BURMA
- BAY OF BENGAL
Accelerometer Sensors on Bridge Deck

Triaxial Accelerometer
(Acceleration in 3 dirs.)

Uniaxial Accelerometer
(Horizontal Transverse Acceleration)
Seismic Data Transmission
Spread Spectrum / GPS

Transmitting from the Bridge

Receiving East End, Bhuapur

Data Control Centre
Continuous digital data is transmitted to the **Data Acquisition Computer**.

Events exceeding threshold acceleration will be recorded on the computer.
Free Field Stations (JMBA-BUET Project)

East Side: Bridge End, Mymensingh, Gazipur
West Side: Bridge End, Bogra, Natore

• Triaxial Accelerometer
• Internal Recorder (PCMCIA Card)
• Solar Panel Charging
Installation Team
Strong Motion Recording
During June 16, 2004 Earthquake

West Free-field (16.06.04)

East Free-field (16.06.04)

Mymensingh Free-field (16.06.04)
West Free-field (NS-component; 16.06.04)

- Acceleration
  - cm/s²
  - Frequency (Hz)
- Velocity
  - mm/s
- Displacement
  - mm

Fourier Spectrum (cm/s²)

Amplitude Ratio

FF-WEST

EQ: 16.06.04

EW

NS

UD

EQ

141003

191103

180304

030704

 Frequency (Hz)

Amplitude Ratio

EQ

16.06.04

 EW

 NS

 UD

 Fourier Spectrum (cm/s)

 Frequency (Hz)
COSMOS-WSSI Project
(60 SMA-1 Type Accelerographs)

Equipment donated by USGS in 2005
Microzonation Maps based on SPT-N value and Microtremor Study
COMBINED HAZARD INTENSITY MAP FOR DHAKA, BANGLADESH
Thank You