Statistical Analysis of Building Damage in Japan based on the 2016 Kumamoto Earthquake

November 14, 2018

Fumio Yamazaki¹), Takuya Suto¹), Masashi Matsuoka²), Kei Horie³), Munenari Inoguchi⁴), Wen Liu¹)

¹) Chiba University, Chiba, Japan.
²) Tokyo Institute of Technology, Yokohama, Japan.
³) MS&AD InterRisk Research & Consulting, Inc., Tokyo, Japan.
⁴) Toyama University, Toyama, Japan.
Earthquake Damage Assessment Flow

- Inventory Data of Buildings & Infrastructures
- Subsurface Soil Data
- Base Rock Motion
- Fragility Curve
- Damage Distribution
Building damage in Mashiki Town

April 16
Background

Empirical fragility curves developed from the 1995 Kobe earthquake have been widely used in Japan. But 23 years have passed since the event.

Significant building damages were caused in the April 2016 Kumamoto earthquake, and the Mashiki Town Government carried out the unified damage assessment for all the buildings in the town.

Objective of the Research

To analyze the building damage data in Mashiki Town compiled by the town government

To develop fragility curves considering the structural material and construction period
Shake maps of the two Kumamoto events

2016/04/14  21:35
Mw 6.2 (Mj 6.5)

2016/04/16 01:25
Mw 7.0 (Mj 7.3)

http://map03.ecom-plat.jp/map/map/?cid=20&gid=587&mid=2892
Causative faults and GNSS stations in the 2016 Kumamoto earthquake

GEONET Kumamoto

GEONET Choyo

Kumamoto City

Mashiki Town

Futagawa fault

Hinagu fault

MW 7.0

MW 6.2

MW 6.0

44 cm

75 cm

97 cm

25 cm
Result of damage (loss) assessment by Mashiki Town Gov. (2017)

- No damage (158)
- Minor (4325)
- Moderate – (2442)
- Moderate + (791)
- Major (3026)
Building damage in the central Mashiki by the town government

- No damage (158) 無被害
- Minor (4325) 一部損壊
- Moderate – (2442) 半壊
- Moderate + (791) 大規模半壊
- Major (3026) 全壊
Result of field survey by BRI and AIJ Kyushu branch based on Damage Grade of Okada & Takai (2000)

Damage Grade
- D0 無被害 631
- D1 一部損壊 600
- D2 一部損壊 263
- D3 半壊 282
- D4 全壊 254
- D5 全壊・倒壊 236
- D6 全壊・倒壊 74

Total 2340
Earthquake loss evaluation class of buildings in Japan and schematic images of other damage classification methods

<table>
<thead>
<tr>
<th>Current Damage (Loss) Class</th>
<th>Former Damage (Loss) Class</th>
<th>Loss Ratio ($r$), Damage Index</th>
<th>EMS-98</th>
<th>Okada &amp; Takai (2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>Major</td>
<td>$r \geq 60%$</td>
<td>G4</td>
<td>D4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$50% \leq r &lt; 60%$</td>
<td>G5</td>
<td>D5</td>
</tr>
<tr>
<td>Moderate +</td>
<td>Moderate</td>
<td>$40% \leq r &lt; 50%$</td>
<td>G3</td>
<td>D3</td>
</tr>
<tr>
<td>Moderate –</td>
<td>Moderate</td>
<td>$20% \leq r &lt; 40%$</td>
<td>G2</td>
<td>D2</td>
</tr>
<tr>
<td>Minor</td>
<td>Minor</td>
<td>$0% &lt; r &lt; 20%$</td>
<td>G1</td>
<td>D1</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>$r = 0%$</td>
<td>(G0)</td>
<td>D0</td>
</tr>
</tbody>
</table>

*Assuming the Loss Ratio ($r$) and the Damage Index (DI) are equal*

Comparison of damage classifications of buildings in the central Mashiki Town

<table>
<thead>
<tr>
<th>Mashiki Town Gov.</th>
<th>AIJ’s survey</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D0</td>
</tr>
<tr>
<td>No damage</td>
<td>1</td>
</tr>
<tr>
<td>Minor</td>
<td>175</td>
</tr>
<tr>
<td>Moderate -</td>
<td>103</td>
</tr>
<tr>
<td>Moderate +</td>
<td>7</td>
</tr>
<tr>
<td>Major</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>304</td>
</tr>
</tbody>
</table>
Damage classification of buildings by local governments with respect to the structural type

(a) Mashiki Town in 2016 Kumamoto EQ

(b) Nada Ward in 1995 Kobe EQ

Murao & Yamazaki (1999)
Revision of building’s seismic code in Japan

- 1970: Tohoku EQ
- 1995: Kobe EQ
- 2007: Niigata-Chuetsu-Oki EQ
- 2011: Tohoku EQ

1950 - 1960: Tokachi-Oki EQ (1968)
1970 - 1980: Modification of the old code
1980 - 1990: Modification of the new code
1990 - 2010: Building Standard Law

Damage ratio of RC buildings in Nada Ward classified by construction period

Murao & Yamazaki (1999)
Damage classification of wooden buildings in Mashiki Town with respect to construction period and construction year
Compares the major damage ratio class for wooden buildings with respect to the construction period for four different datasets in Japan.
Estimated peak ground velocity (PGV) distribution and site amplification ratio in a 250-m grid in Mashiki Town
Development of fragility curves for Wooden, S and LS buildings

- Wooden (Nishinomiya City)
  - 1995 Kobe EQ
- Wooden (Nada Ward)
  - 1995 Kobe EQ
- Wooden (Mashiki Town)
  - 2016 Kumamoto EQ

Major damage ratio vs. PGV (cm/s)

- ln (PGV)
- MAJOR DAMAGE RATIO

Wooden (Nishinomiya City)
1995 Kobe EQ
Wooden (Nada Ward)
1995 Kobe EQ
Wooden (Mashiki Town)
2016 Kumamoto EQ

Mashiki
Development of fragility curves for wooden buildings in Mashiki town with respect to the construction period

Major damage
Conclusions

- Building damage data surveyed by Mashiki Town Government were analyzed with respect to the structural material and construction period.

- The damage ratios of buildings in Mashiki Town were similar levels with those in Nada Ward due the 1995 Kobe earthquake.

- Fragility curves were developed for wooden buildings for different construction periods corresponding the revisions of seismic code in Japan. The developed curves are recommended to use for damage assessment of future earthquakes in Japan.
Thank you very much!