Correlation of Ground Motion Intensity to Structural Demands Considering Event Characteristics

Andrew O’Donnell and Dr. Tao Lai
June 27, 2018
Catastrophic Loss Modeling Framework

HAZARD
- Event Generation
- Intensity Calculation
- Exposure Information

ENGINEERING
- Damage Estimation
- Policy Conditions

FINANCIAL
- Insured Loss Calculations

© 2017 AIR Worldwide
Objective and Motivation

Nonlinear Dynamic Analysis

Representative Buildings

Numerical Models

Subjected to Globally Sourced Ground Motion Records

Damage Estimation

Damage Ratio

DF Development

- Wood Frame
- Unreinforced Masonry
- Reinforced Masonry
- Reinforced Concrete Shear Wall
- Reinforced Concrete Frame
- Tilt-Up
- Pre-Cast

Sa (0.3 seconds) (g)

$\ddot{u}(t)$ $u(t)$ $\ddot{u}(t)$ $u(t)$ $\ddot{u}(t)$ $u(t)$ $\ddot{u}(t)$ $u(t)$ $\ddot{u}(t)$ $u(t)$ $\ddot{u}(t)$ $u(t)$
Methodology

Example Capacity Curves for Reinforced Concrete

Example shown for:
RC, Midrise, Pre Code

\[ PFA \]
\[ MIDR \]

\[ CorCoeff = 0.97 \]

\[ CorCoeff = 0.72 \]

PGA, Sa(0.3), etc.

\( Mw, r, t \)

4800 Unique Ground Motions

\[ A (g) \]
\[ D (in) \]
Employing the Coefficient of Multiple Correlation

- **Predictor variables:**
  - PGA, Sa(0.3), Sa(1.0), Sa(2.0)
  - Mw, r, t

- **Target Variables:**
  - MIDR, PFA

\[ \text{CoMC}^2 = c^\top R_{xx}^{-1}c \]

- \( R_{xx} \) = matrix of correlations between the individual predictor variables
  - Example: PGA\(_i\) and Mw\(_i\)

- C = column vector of correlation coefficients between predictor variables and target variables
  - Example: PGA\(_i\), Mw\(_i\), and MIDR\(_i\)

<table>
<thead>
<tr>
<th>Intensity Measure, IM</th>
<th>Baseline</th>
<th>Magnitude, Mw</th>
<th>Source-to-site Distance, r</th>
<th>Duration, t</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGA</td>
<td>PGA(_b)</td>
<td>PGA, Mw</td>
<td>PGA, r</td>
<td>PGA, t</td>
</tr>
<tr>
<td>Sa(0.3)</td>
<td>Sa(0.3)(_b)</td>
<td>Sa(0.3), Mw</td>
<td>Sa(0.3), r</td>
<td>Sa(0.3), t</td>
</tr>
<tr>
<td>Sa(1.0)</td>
<td>Sa(1.0)(_b)</td>
<td>Sa(1.0), Mw</td>
<td>Sa(1.0), r</td>
<td>Sa(1.0), t</td>
</tr>
<tr>
<td>Sa(2.0)</td>
<td>Sa(2.0)(_b)</td>
<td>Sa(2.0), Mw</td>
<td>Sa(2.0), r</td>
<td>Sa(2.0), t</td>
</tr>
</tbody>
</table>
PGA and Sa(0.3) correlate better with PFA
Sa(1.0) and Sa(2.0) correlate better with MIDR

O = PFA
+ = MIDR
For PGA and Sa(0.3) including magnitude improves correlation with MIDR
For Sa(1.0) and Sa(2.0) including distance improves correlation with PFA
Inclusion of distance improves correlation between $\text{Sa}(2.0)$ and PFA

Example shown for: RC, Highrise, Moderate Code, PFA

Improved correlation by 23%

$\text{CorCoeff} = 0.563$

$\text{CorCoeff} = 0.693$
Future Work

The presented study is limited in peak transient response of the structure and a few selected IMs and Characteristics

Purpose of this study was to provide foundational results and establish a framework for future studies

Looking forward we can:
- Expand our set of IMs to include MIV, Arias Intensity, and Cumulative Absolute Velocity (CAV)
- Evaluate more complex response vectors or hysteretic or energy-based damage metrics