Fragility Curves for Assessing the Risks of Debris Flow Hazards, HAZUS compatible format

- Jorge A. Prieto, Murray Journeay and Malaika Ulmi

- NRCan, GSC, Quantifying Geo-hazards Risks Group, Vancouver

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Outline for Today

I) Introduction

II) Past research and New fragility curves for Debris Flow

III) Final comments
El Ruiz, 1985, Colombia. 23,000 people killed. USGS photograph.
Introduction

Páez river basin, Cauca, El Huila volcano, Colombia. 1994 after earthquake lahar/debris flows. USGS photographs.
Introduction

Damage to a house and a barn due to the debris flow force impact. Paez River basin, Cauca, Colombia, 1994. USGS photographs.
Introduction

Belalcazar town, Cauca, Huila Volcano Region., Colombia, 2008. 300 Million m³ debris flow. Successful evacuation. NO casualties. USGS photograph.
Testalinden, BC, 2010
5 houses collapsed, 2 extensive damage
Introduction

Johnsons Landing, debris flow, Kootney lake, BC, July, 2012
3 homes destroyed, 4 casualties.
Introduction

In regards to Debris Flow Risks

-Casualties appear to be decreasing (maybe!).

-Economic damage to property is increasing.

Tools that help us to analyze debris flow risks are needed!
Introduction

DF Risk analyses involves:

- Intensity and probability of the hazard, e.g. DF depth, velocity, combination

- Consequence (damage, casualties) and its probability given the hazard

- Fragility curves: Probability of some state of consequences given intensity of the hazards
Debris Flow Fragility Curves - Past Research

- Fuchs et al. (2007) used a debris flow event in Austria to develop a polynomial function relating vulnerability, \( y \), to debris flow intensity represented by deposition height, \( x \):
  \[
  y = 0.11x^2 - 0.02x
  \]
  (inconsistencies after intensities higher than 1.0m)

- Totschnig et al. (2011) created a damage ratio relating deposition height to the height of the affected building, used as proxy for vulnerability and generated curves.
  (requires reliable loss data)
Debris Flow Fragility Curves - Past Research

- Jakob et al. (2012) examined 68 debris flow case studies with documented damages, flow depths and flow velocities.
- Each case was assigned one of 4 damage classes from nuisance flood/sedimentation to complete destruction.
- Developed intensity index to determine building damage:
  \[ I_{df} = dv^2 \] =Momentum Flux
  where d is max flow depth and v is max flow velocity
- Created matrix of damage probabilities that can be used for any calculated intensity index and then applied to estimate the likely losses.
Debris Flow Fragility Curves - Past Research

<table>
<thead>
<tr>
<th>Damage class</th>
<th>Damage description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some sedimentation (I)</td>
<td>Sediment-laden water ingresses building’s main floor or basement; requires renovation; up to 25% insured loss</td>
</tr>
<tr>
<td>Some structural damage (II)</td>
<td>Some supporting elements damaged and could be repaired with major effort; 25–75% insured loss</td>
</tr>
<tr>
<td>Major structural damage (III)</td>
<td>Damage to crucial building-supporting piles, pillars and walls will likely require complete building reconstruction; &gt;75% insured loss</td>
</tr>
<tr>
<td>Complete destruction (IV)</td>
<td>Structure is completely destroyed and/or physically transported from original location; 100% insured loss</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>0-1</th>
<th>1-101</th>
<th>101-102</th>
<th>102-103</th>
<th>&gt;103</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete destruction (IV)</td>
<td>0</td>
<td>6</td>
<td>25</td>
<td>67</td>
<td>100</td>
</tr>
<tr>
<td>Major structural damage (III)</td>
<td>0</td>
<td>22</td>
<td>38</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>Some structural damage (II)</td>
<td>30</td>
<td>50</td>
<td>37</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Some sedimentation (I)</td>
<td>70</td>
<td>22</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Jakob et al. (2012). Damage classes and probabilities. For each calculated intensity range, the numbers below that range in the table are the likelihood of the associated level of damage.
Debris Flow Fragility Curves - Past Research

- Papathoma-Kohle et al. (2012) developed vulnerability curves that were validated using debris flow events in a village in Italy in August 1987.
- The curves show degree of loss corresponding to process intensity, which is simplified as deposition height.
- The simple curves can be used to predict losses from future events.
Vulnerability curve using a Weibull distribution, with degree of loss plotted against intensity as a measure of deposition height, from Papathoma-Kohle et al. (2012).

- Damage due to Tsunamis was divided:
  - Contents, non structural components: Flood depth
  - Structure: Momentum flux, i.e. Depth*Velocity^2

Damage in earthquakes is produced by the Seismic Lateral Force

From HAZUS technical Manual

Equate Seismic lateral strength to Tsunami hydrodynamic force

From HAZUS technical Manual

The hydrodynamic force depends on Momentum Flux, $h^*v^2$

Produced for: 3 damage states and the 36 structural types used by HAZUS
New Debris Flow fragility curves

- Used a database with 68 documented cases of debris flow.
- Initially we grouped the data according to the damage states used by Jakob et al (2012), and did statistics.
New Debris Flow fragility curves

- Obtained initial Fragility Curves

GSC Debris flow fragility curves

- Some Sedimentation
- Some Structural Damage
- Major Structural Damage
- Complete Damage

Momentum Flux (ft$^3$/s$^2$)

Probability of being in or exceeding...
New Debris Flow fragility curves

- Problem: Damage states defined by Jakob et al 2011 are not consistent with HAZUS.

- Compare initial fragility curves, for one Damage State, with equivalent Tsunami fragility curves developed by Kircher (2012).
New Debris Flow fragility curves

- There is significance correlation between fragility curves due to Tsunamis and Debris Flow.

- Then, we used the same procedure for developing the Tsunami curves (Kircher 2012) to produce Debris Flow FC for the same damage states and 36 types of buildings given by HAZUS. Plus a modification to allow for denser sediments in the case of debris flows.
New Debris Flow fragility curves

<table>
<thead>
<tr>
<th>HAZUS TYPE</th>
<th>Moder</th>
<th>Extens</th>
<th>Compl.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>β</td>
<td>Median</td>
</tr>
<tr>
<td></td>
<td>Ft³/s²</td>
<td>sdn</td>
<td>Ft³/s²</td>
</tr>
<tr>
<td>W1</td>
<td>188</td>
<td>0.88</td>
<td>188</td>
</tr>
<tr>
<td>W2</td>
<td>349</td>
<td>0.87</td>
<td>349</td>
</tr>
<tr>
<td>S1L</td>
<td>997</td>
<td>0.84</td>
<td>997</td>
</tr>
<tr>
<td>S1M</td>
<td>1,307</td>
<td>0.87</td>
<td>2,614</td>
</tr>
<tr>
<td>S1H</td>
<td>2,001</td>
<td>0.87</td>
<td>4,003</td>
</tr>
<tr>
<td>S2L</td>
<td>1,139</td>
<td>0.73</td>
<td>1,122</td>
</tr>
<tr>
<td>S2M</td>
<td>2,624</td>
<td>0.76</td>
<td>3,928</td>
</tr>
<tr>
<td>S2H</td>
<td>4,495</td>
<td>0.76</td>
<td>6,744</td>
</tr>
<tr>
<td>S3</td>
<td>210</td>
<td>0.77</td>
<td>210</td>
</tr>
<tr>
<td>S4L</td>
<td>1,167</td>
<td>0.76</td>
<td>1,167</td>
</tr>
<tr>
<td>S4M</td>
<td>2,322</td>
<td>0.78</td>
<td>3,779</td>
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<tr>
<td>S4H</td>
<td>4,012</td>
<td>0.78</td>
<td>6,490</td>
</tr>
<tr>
<td>S5L</td>
<td>673</td>
<td>0.73</td>
<td>673</td>
</tr>
<tr>
<td>S5M</td>
<td>1,449</td>
<td>0.76</td>
<td>2,182</td>
</tr>
<tr>
<td>S5H</td>
<td>2,478</td>
<td>0.76</td>
<td>3,736</td>
</tr>
<tr>
<td>C1L</td>
<td>1,197</td>
<td>0.84</td>
<td>1,197</td>
</tr>
<tr>
<td>C1M</td>
<td>1,937</td>
<td>0.87</td>
<td>3,873</td>
</tr>
<tr>
<td>C1H</td>
<td>2,053</td>
<td>0.78</td>
<td>4,105</td>
</tr>
<tr>
<td>C2L</td>
<td>1,571</td>
<td>0.81</td>
<td>1,571</td>
</tr>
<tr>
<td>C2M</td>
<td>2,915</td>
<td>0.81</td>
<td>5,097</td>
</tr>
</tbody>
</table>
Final Comments

The use of Tsunami Flow curves for analyses of Debris Flow is based on two considerations:

- The physics implied in the process of lateral deformation/damage of a building,
- Empirical evidence provided by available data.
Questions?
References


