Disaster Risk Assessment: Understanding Hazard Process and Complex Disasters

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23 Nov 2017
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Outline

- Complex disasters
- Dynamic process
- Disaster risk assessment
1. Complex Disaster

1.1 Disaster Impact to Social Economy

Human Beings under threat from natural hazards

Natural Hazards occurred in 2014

Earthquake

Flood

Storm

Fire

Debris flow

Drought

Snow
1.2 Mega Disaster Events

◆ Debris Flow (Zhouqu, China)

Aug 8, 2010, Zhouqu debris flow caused over 2000 death and 22667 homeless, destroyed half county
◆ Landslide Lake (Attabad, Pakistan 2010)

Block Highway Between China-Pakistan for 4 Year
Damage to Road and Bridge

Scour Road/Bridge Foundation

Block Culvert
1.3 Complex Hazard: Typical Mountain Hazard Chain

Animation from Japan

- Landslide
- Dammed Lake
- Dam Breakage
- Outburst Flood / Debris Flow
1.4 Hazard Chain at Ying Xiu Town

- **Hazard Chain**
  
  I. Larger Affected Range
  
  II. Longer Affected Period
  
  III. Greater Damage
2. Dynamic Process

2.1 Debris Flow Process and Simulation

Develop physical model to simulate the debris flow movement, the results of simulation are used to determine the hazardous area and dynamic parameters onward disaster risk analysis.
2.2 Control Equation for Debris Flow Two Phase model with Bed Erosion

**Fluid Phase**

\[
\frac{\partial h \alpha_p}{\partial t} + \frac{\partial}{\partial x} (h \alpha_p u_f) + \frac{\partial}{\partial y} (h \alpha_p v_f) = pE
\]

\[
\frac{\partial (\alpha_p hu_f)}{\partial t} + \frac{\partial (\alpha_p hu_f^2)}{\partial x} + \frac{\partial (\alpha_p hu_f v_f)}{\partial y} = -gh \frac{\partial (z_b + h)}{\partial x} - \frac{\alpha_f}{\rho_f} \left( \frac{u_f}{\sqrt{u_f^2 + v_f^2}} \right) \tau_b + 3 \mu \frac{u_f}{h} + \alpha_f \mu \frac{\partial^2 u_f}{\partial x^2} + \alpha_f \mu \frac{\partial^2 u_f}{\partial y^2} - \left( \frac{\rho_s}{\rho_f} - 1 \right) \frac{h(1 - \alpha_s)}{v_T(1 - \alpha_s)^m} (u_f - u_s) + u_f pE
\]

**Bed Erosion**

\[
\frac{\partial z_b}{\partial t} = -E
\]

**Solid Phase**

\[
\frac{\partial h \alpha_s}{\partial t} + \frac{\partial}{\partial x} (h \alpha_s u_s) + \frac{\partial}{\partial y} (h \alpha_s v_s) = (1 - p)E
\]

\[
\frac{\partial (\alpha_s hu_s)}{\partial t} + \frac{\partial (\alpha_s hu_s^2)}{\partial x} + \frac{\partial (\alpha_s hu_s v_s)}{\partial y} = -\frac{v_s}{\sqrt{u_s^2 + v_s^2}} \alpha_s (1 - \frac{\rho_f}{\rho_s}) g h \tan \phi_{bed} - gh \frac{\rho_f}{\rho_s} \alpha_s k_{act/pass} \frac{\partial (z_b + h)}{\partial x} + (1 - \frac{\rho_f}{\rho_s}) \frac{h(1 - \alpha_s)}{v_T(1 - \alpha_s)^2} (u_f - u_s) + u_s (1 - p)E
\]

Consider the effect of solid and slurry phase interaction in debris flow and its bed erosion, a two-phase model was developed to simulate the flow movement. Dynamic parameters such as velocity and flow depth could be extracted for hazards and vulnerability assessment.
Full Process Simulation: Formation-Movement-Deposition
Dynamic Parameter Extraction at Anytime in a computational grid
Forward Modeling instead of back analysis
3. Risk Assessment

3.1 Conceptual model of disaster risk

\[ R = f(H, V, E) = H \times V \times E \]

\[ R = H \times V \]

- **R** - Risk degree (0~1)
- **H** - Hazard degree (0~1)
- **V** - Vulnerability degree (0~1)
- **E** - Exposure degree (0~1)

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Risk identification

Hazard Analysis

Vulnerability Analysis

- **Risk calculation**
- **Normalization**
- **Risk grading**
- **Risk mapping**

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Mountain hazards
Formative environment
Hazard Distribution
Hazard characteristics
Susceptibility zoning

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Evaluation
Analytical methods
Analytical methods
Analytical methods

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Over-Analysis
Regional risk
Single hazard risk
Ensemble risk

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Types
Numbers
Database
Exposure
Vulnerability
Susceptibility

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Risk Assessment for mountain hazards
3.2 Hazard assessment

Impact and inundation are the main mode of damage caused by debris flow, the following parameters are selected to represent its hazard:

Hazard of impact is represented by maximum momentum:  \( D_e = A \cdot \max_{t>0} [(u^2 + v^2)h\rho] \)

Hazard of Inundation is described by height of debris flow:  \( h = \frac{N_{i,j}\Delta V}{A} \)

Debris flow is a mixed flow of boulders and slurry which consist of water, clay and sand.

- **slurry**: continuous flow
- **boulders**: discrete movement

**Dynamic Based Assessment**

Simulation of Zhouqu DF
3.3 Vulnerability Assessment

- Debris Flow Slurry and Boulder Impact Isolation

\[
f(t) = \sum_{k=-\infty}^{+\infty} c_{j,k} \phi_{j,k}(t) + \sum_{j=-\infty}^{+\infty} \sum_{k=-\infty}^{+\infty} d_{j,k} \psi_{j,k}(t)
\]

- Structure Response to Impact

- Building Vulnerability Curve
◆ **Case Study:** Risk Assessment at Qing Pin Town
Risk Calculation

H:

V:

R:
**Result Verification**

- **Actual Affected Area**: 1,482,345.1 m², Simulated results 1,439,488.2 m², different by 2.9%.

### Estimated Damage against Actual Damage

<table>
<thead>
<tr>
<th>承灾体分类</th>
<th>高风险区</th>
<th>中风险区</th>
<th>低风险区</th>
<th>分类合计</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>模拟范围内灾损值</td>
<td>实际灾损值</td>
<td>偏差（%）</td>
<td>模拟范围内灾损值</td>
</tr>
<tr>
<td>房屋建筑(m²)</td>
<td>135,000</td>
<td>134,000</td>
<td>0.7</td>
<td>25,000</td>
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<tr>
<td>道路设施(m)</td>
<td>6,900</td>
<td>6,800</td>
<td>1.5</td>
<td>1,000</td>
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<tr>
<td>耕地(m²)</td>
<td>498,000</td>
<td>495,000</td>
<td>0.6</td>
<td>66,000</td>
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<tr>
<td>林草地(m²)</td>
<td>112,000</td>
<td>107,000</td>
<td>4.7</td>
<td>35,000</td>
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</table>
Type of Damage from Debris Flow

- Direct damage to foundation or inundation
- Inundation from dammed lake due to debris flow deposition
- Outburst flood of dammed lake cause scouring and erosion
Mountain hazards Risk Analysis at Different Scale

**Local**
- For road design

**Sectional**
- For localized route selection and refinement

**Overall**
- Overall route planning
**Systematic debris flow treatment**

Based on the maximum sediment transport capacity of river, reduce the scale of debris and discharge, dissipate energy, regulate the debris-flow formation conditions and diminish the damage power of debris flow.
Thank You for your attention!