Keywords: Accumulated precipitation, DEBRIS-2D; hazard area

1 Introduction

Debris flow warning system in Taiwan uses effective accumulated precipitation as warning criteria (Lee et al., 2006). Little research studied the affected area associated with different accumulated precipitation. In this paper, Taipei DF024 potential debris flow torrent is used as an example to study the relation between affected area and accumulated precipitation. Refer to the past typhoon and rainfall event in Taipei, Taiwan, three different accumulated precipitation 300, 500 (official warning criteria) and 700 mm in 24 hours are chosen for comparison.

In debris flow simulation, there have been several successful predictions in real debris flow event by DEBRIS-2D (Liu & Huang, 2006; Liu et al. 2009; Tsai et al. 2011). Wu et al. (2013) also compared two popular numerical simulation programs, FLO-2D and DEBRIS-2D, the results show that DEBRIS-2D gives better assessment in hazard area delineating and flow depth predicting, granular debris flow especially. Therefore, DEBRIS-2D is used to simulate debris flows in our study area.

2 Debris flow simulation

The main inputs in DEBRIS-2D are topography and initial debris source distribution. The only rheological parameter, yield stress, must be measured by sample (Liu & Huang, 2006; Coussot & Boyer, 1995) and the value is estimated as 750Pa. From field investigation, one can find the dry debris volume $V_d$ and its corresponding triggering locations as shown in Table 1, Figure 1(a). Then the debris flow volume can be determined by equilibrium concentration formula (Takahashi, 1981), the equilibrium solid volume concentration $C_{se}$ can be expressed as

$$C_{se} = \frac{\rho \tan \theta}{(\sigma - \rho)(\tan \phi - \tan \theta)} \leq 0.603,$$

(1)

where $\rho$ is water density; $\sigma$ is the density of dry debris; $\phi$ is internal friction angel; $\theta$ is average creek bottom slope. From field samples, and can be measured as 2.6 g/cm$^3$ and 37° respectively. From Digital Terrain Model, can be calculated as 21.8°. With the water density of 1 g/cm$^3$, the equilibrium concentration $C_{se}$ was calculated as 0.685 by Eq. (1) and can be estimated as 0.603 due to the maximum value of $C_{se}$ cannot exceed 0.603. The volume $V'_f$ of debris flow can be calculated as $V_d / C_{se}$ and shown as Table 1.

<table>
<thead>
<tr>
<th>Table 1, Conversion of debris flow volume</th>
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<tbody>
<tr>
<td>Dry Debris Volume $V_d$ (m$^3$)</td>
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<tr>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Pt 1</td>
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<tr>
<td>Pt 2</td>
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<tr>
<td>Pt 3</td>
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<td>Total</td>
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In addition to dry debris, the sufficient water is also the key factor to induce debris flow. Therefore, we used a different approach by using different accumulated rainfall to estimate the debris flow volume. By using Monobe formula, one can find the relation between average rainfall intensity per hour $I$ and accumulated rainfall in 24 hours $R_{24}$ as

$$I = (R_{24}/24)(24/t_c)^{2/3},$$

(2)

where $t_c$ is concentration time and the value can be estimated through kinematic wave formula (Wooding, 1965) as follows

$$t_c = \left(\frac{n_e L_e}{\sqrt{S_e L_e^{0.67}}}ight)^0.6 + \frac{B}{2l_c} \left(\frac{2l_e n_e L_e L_e}{\sqrt{S_e B}}\right)^{0.6} + \frac{B}{2l_c} \left(\frac{2l_e n_e L_e L_e}{\sqrt{S_e B}}\right)^{0.6},$$

(3)

where $n_e$ and $n_e'$ are roughness coefficients for surface flow and channel flow respectively; $L_e$ and $L'_e$ are surface-flow length and channel length respectively; $S_e$ and $S'_e$ are surface-flow slope and channel slope respectively; $B$ is channel width; $l_c$ is effective rainfall intensity. and can be calibrated as 1 and 0.6 (Lee, 2003). From Digital Terrain
Model, $L_o, L_s, S_o, S_s, B$ can be calculated as 65.08m, 586.67m, 0.5, 0.39, 2m, respectively. By recursive calculation in Eq. (2) and (3), the average and effective rainfall intensity can be determined as shown in Table 2.

Peak flow rate $Q_p$ is estimated by Rational formula and the total water volume $V_w$ can be estimated as $0.5 \cdot Q_p \cdot t$. Based on equilibrium concentration conceptual, the volume of debris flow $V_d$ can be calculated as $V_u / (1 - C_{de})$ and shown as Table 2.

If $V_d - V_u$ is negative value, it means debris control the debris flow. Otherwise, water volume or rainfall control the debris flow when $V_d - V_u$ is positive. From field survey, the maximum erosion depth can be estimated as 1m. Therefore, we assume the extra debris flow volume $(V_d - V_u)$ will be induced from bed erosion, and the erosion area can be calculated as Table 2 and distributed as fig. 1(a).

3 Concluding remarks

We assume different accumulated precipitation will induce different scale of landslide mass, erosion effect, and debris flow. The results show that hazard area is proportional to precipitation, and the thickness of maximum debris flow accumulation is between 3 and 3.5 m as shown in Fig. 1(b). The road in front of the house will be blocked in all cases.

The relation between accumulated precipitation and hazard area can provide officials additional information on resident evacuation and design of countermeasure.

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References


