# Boundary erosion by granular flows in centrifuge experiments: preliminary results

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## INTRODUCTION

**Fig. 1** Bed-rock erosion in Pu-Tun-Pu-Nas River

When flowing through bedrock canyons or past reinforced concrete structures, debris flows can abrade and damage lateral and bottom boundaries. This is difficult to investigate in situ during events, as their timing and location is difficult to anticipate, and debris flows can easily destroy instrumentation. Knowledge gained from the field is therefore mostly limited to observations acquired after the events. Debris flow will leave the changes of the terrace, debris deposit fan or the change of canyon. During study the change of morphology in field, we can conjecture the actual situation of debris flow. In southern Taiwan, tributary watershed of the Laonong River in which massive landslide occurred in August 2009 due to Typhoon Morakot , a huge debris flow happened, which leave a debris fan on Laonong River.

Beside the debris fan, debris flow also eroded the bed rock in the canyon (Fig. 1). In this study we want to understand the relationship between debris flow rheology and canyon bed rock eroded morphology. To simulate the bedrock erosion, we conduct the experiment with drum system which can be imagined as an infinite long channel with bed rock, the bed-erosion happens during the rotation. To obtain realistic stress level in small scales, we introduce the centrifuge to help us to do the experiments.

## EXPERIMENTAL SET UP

### -Simple Theory

We introduce a simplified theory to help us to design the experimental equipment in centrifuge. We describe the flow situation in drum when it is half-full. The drum rotate with the constant angle velocity $\omega$, which incline the particles to the rest angle (**Fig.2**). The particle start moving which become the boundary layer with depth $h$. We can simplify the flow situation by assuming the rotation of drum can be translated to a source rotation. We can find

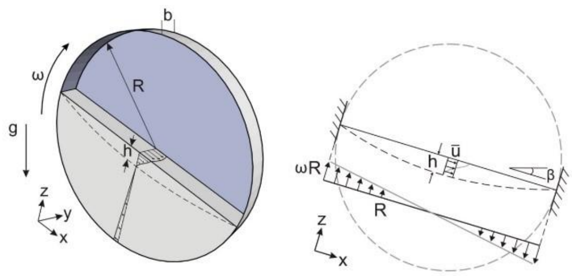


**Fig. 2** The sketch of drum system

out when $R >> h$ indicated $\bar{u} >> w$ . If the velocity in z-axis is much smaller than the velocity in x-axis, we can apply the shallow water theory in this case. We are going to introduce the simply theory of shallow water flow in steady and uniform case.

**-Experimental set up constraint**

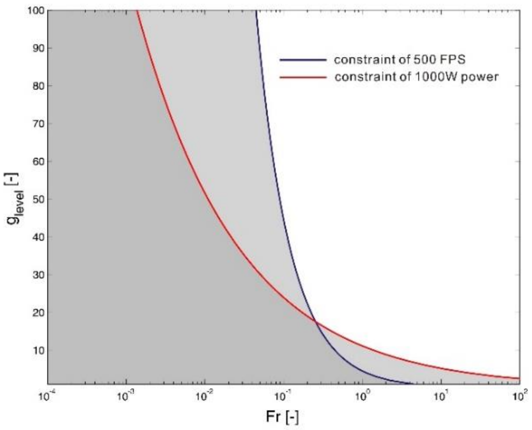


**Fig. 3** Parameter space accessible to experimentation

Follow this assumption, we introduce the linearized dense granular flow rheology [GDR MiDi 2004; da Cruz et al. 2005; Berzi and Jenkins 2009] in to shallow water theory. And base on this assumption we can do a simple dimensionless analysis, and find out a dimensionless number, Froude Number $Fr$ , which defined as $Fr = \omega^2 R / g$ . By using this dimensionless number, we introduce the limits of doing centrifuge experiment, power supply and frame rate of the camera. The relationship we derived can be illustrated in Fig.9, which shows the functional area through the centrifuge experiments.

**-Imaging measurements**

The major measurement while experiment runs is velocity tracking and DTM scanning. For the velocity tracking, we apply the simple PTV tracking method and apply the idea of stream function to clear the noise in the velocity field. For the DTM scanning, we use the PhotoScan, providing 16 photos in different angles and carefully calibration, we can get the terrace with ~0.1 mm error.

**PRELIMINARY RESULTS**

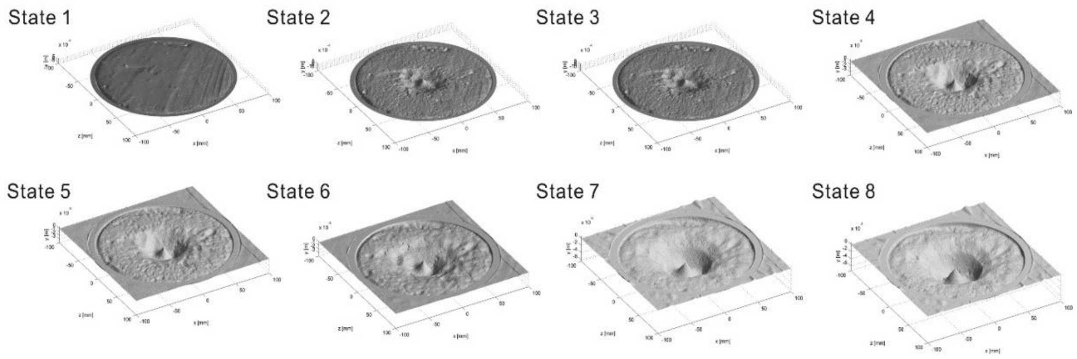


**Fig. 4** DTM of erosion plate for successive states

We run the experiments in varied g level, and rotation rate. Change the rotation rate from low rotation rate to high rotation rate, the free surface began to deform, the slope increase with rotation rate and the flow depth increase with rotation rate. For the same rotation rate, the mean velocity in flow layer is getting larger when we rise the drum to higher g level, flow depth decrease with g level. We performed a series of bed rock erosion experiments. By using the same bed rock sample, the difference only laid on the flow condition. From **Fig. 4**, the special shape of the erosion plate can be observed. In the middle of the erosion plate did not get eroded, the shape of granular flow will get curving in high g level which protect the middle from erode.

**Keywords: debris flow, bulking, hazard, centrifuge,experiments**