Influences & Preventions of Granular Flow

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Outline

- *Motivation*
- *Theory*
- *Purpose*
- *Experimental setup*
- *Experimental steps*
- *Experimental analysis*
- *Experimental results*
- *Conclusion*

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Motivation

We are curious about the effect of retaining wall on mudslide.

How far?

How many?

Material	*Representation*
EVA balls	*Collapse*
BB shots	*Mudslide*

Theory (Vertical motion)

The sediment collapses under the effect of gravity, and the motion is equivalent to uniform acceleration.

$$H(x,t) = H_0 - \frac{1}{2}\alpha g(t - t_{0z})^2$$

α: *vertical effective gravity constant*
t_{0z}: *the time when granular flow starts*

Theory (Horizontal motion)

Since particles are affected by gravity and normal force, their motion should be proportional to uniform acceleration.

$$L(z,t) = L_0 + \frac{1}{2}\beta g(t - t_{0x})^2$$

β: *horizontal effective gravity constant*

t_{0x}: *when the time the sliding gate starts to move.*

Purpose

- *Observe the phenomenon of the granular flow*
  1. *A uniform accelerated motion phenomenon.*
  2. *Final height and overflow distance.* $(H_f \text{ and } \Delta L_f = L_f - L_0)$
- *Observe the effect of the retaining wall*
  1. *Lost percentage of granular flow.*
  2. *Overflow distance .* $(\Delta L_f = L_f - L_0)$
  3. *EVA balls vs BB shots. (collapse vs mudslide)*

Experimental setup

Angle steel

DC motor

Acrylic plate

Aluminum block

Materials:

BB shots

EVA balls

Sliding gate

Experimental steps

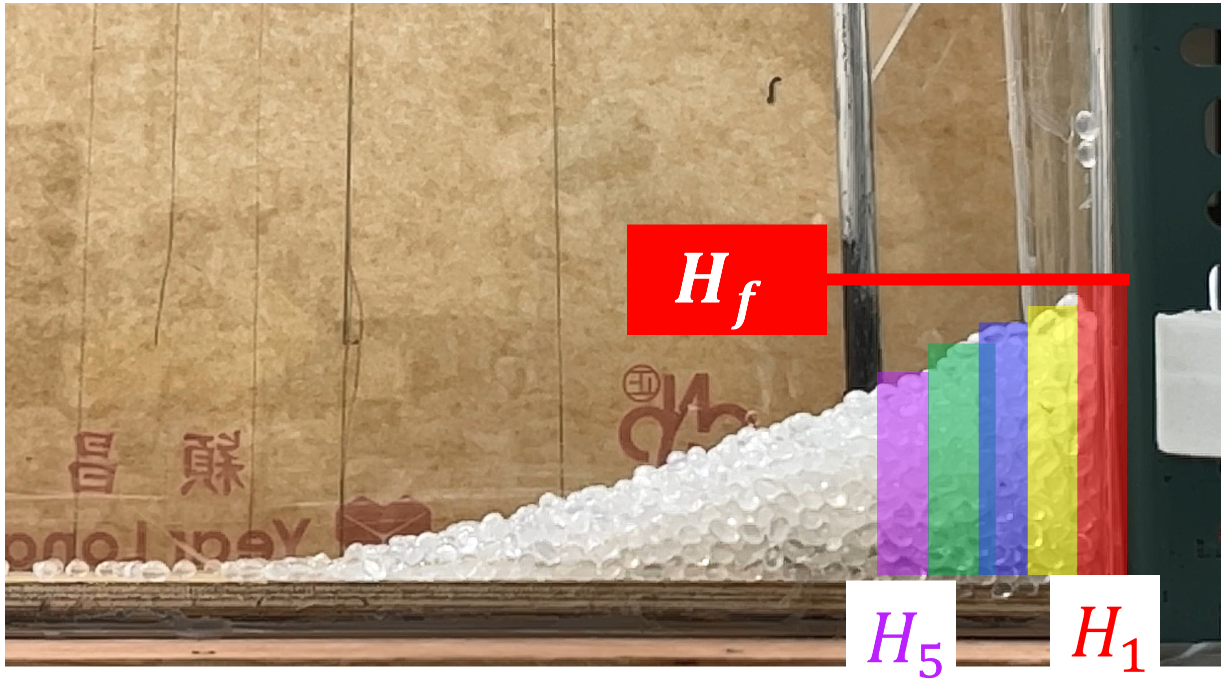
Put the EVA balls or BB shots into the chamber.

Analyze the video without retaining wall.

Analyze the video with retaining wall.

Experimental analysis

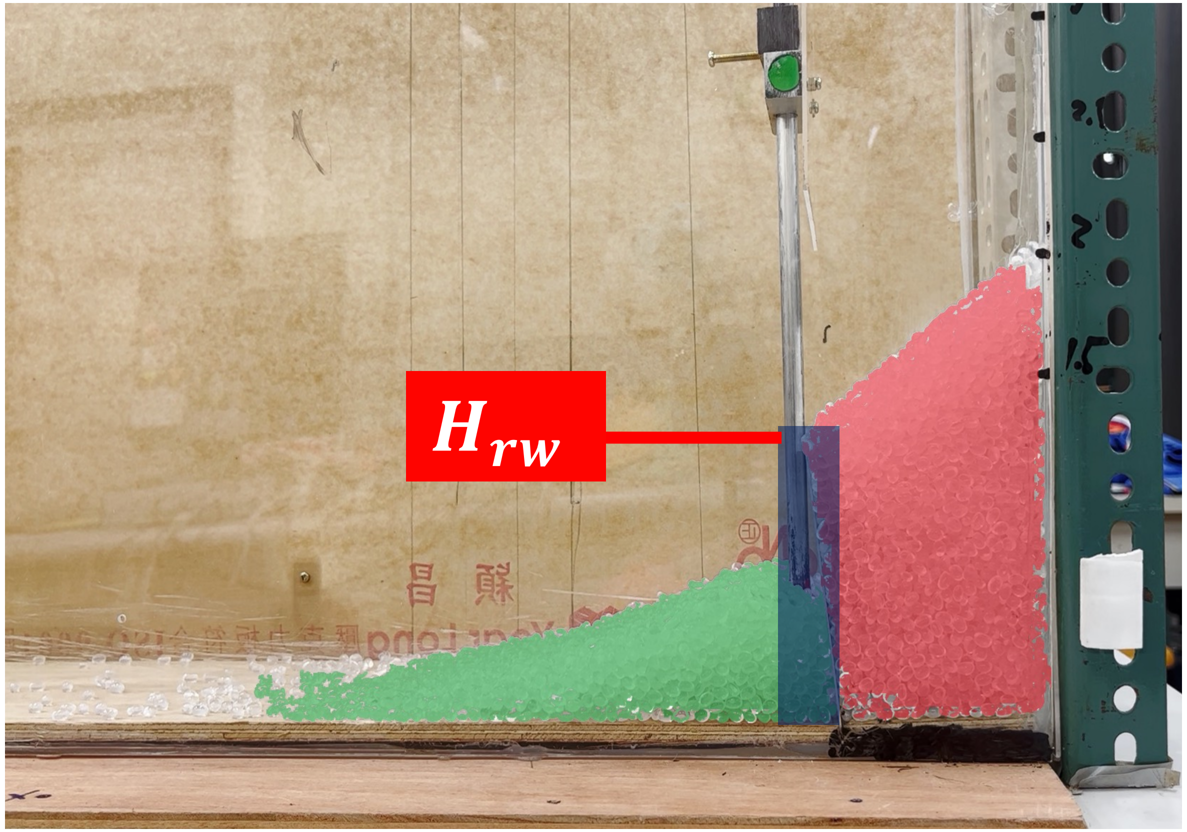
-Height and overflow distance



- *Final height and overflow distance:* H_f *and* $\Delta L_f = L_f - L_0$
- *Time evolution of height and length:* $H_1 \ldots\ldots H_5$, $L_1 \ldots\ldots L_5$

Experimental analysis

- With retaining wall



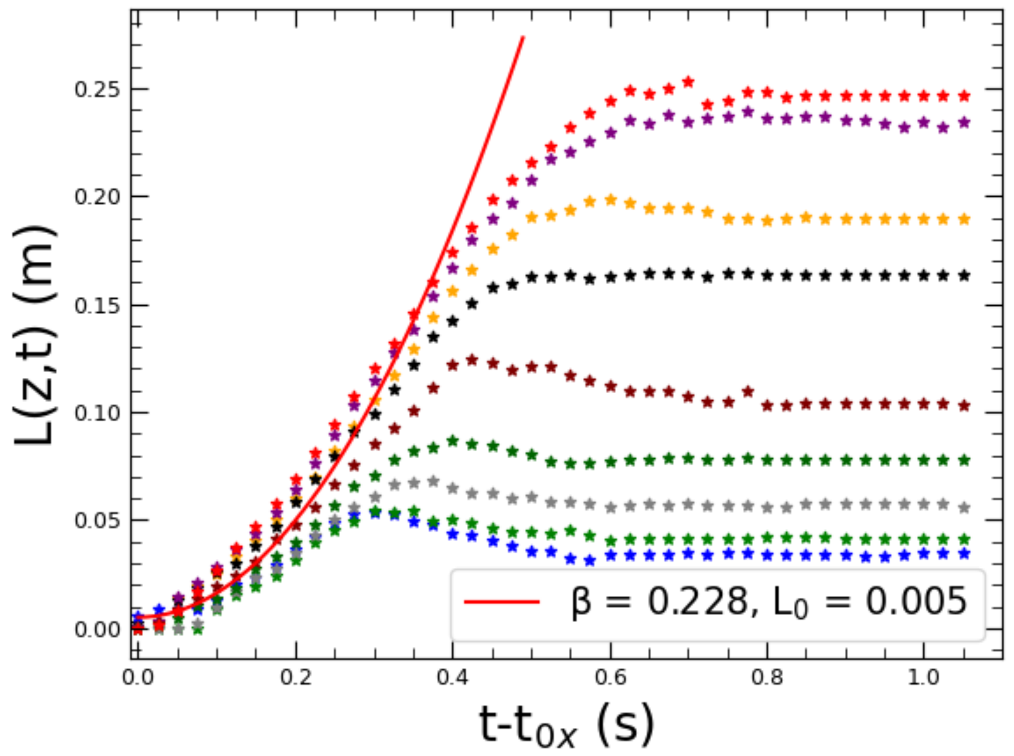
Calculate the loss ratio under different aspect ratios.

$$aspect\ ratio = \frac{H_0}{L_0}$$

$$loss\ ratio = \frac{Green\ Area}{Red\ Area}$$

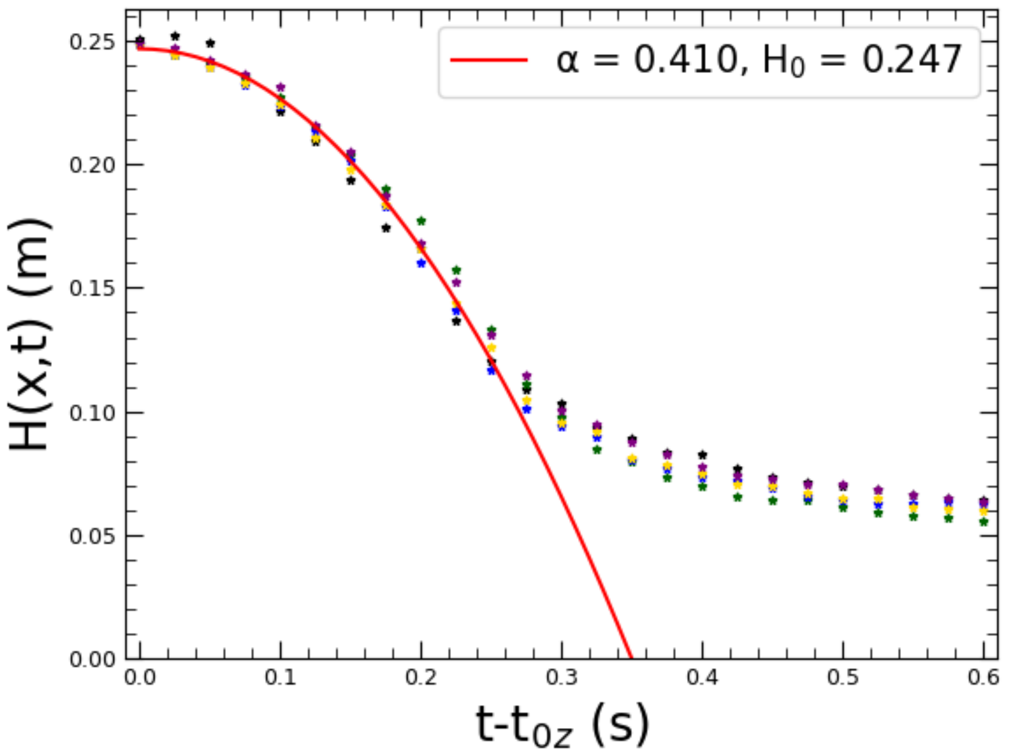
$$H_{rw} = \text{ the height of retaining wall}$$

Result: Horizontal analysis



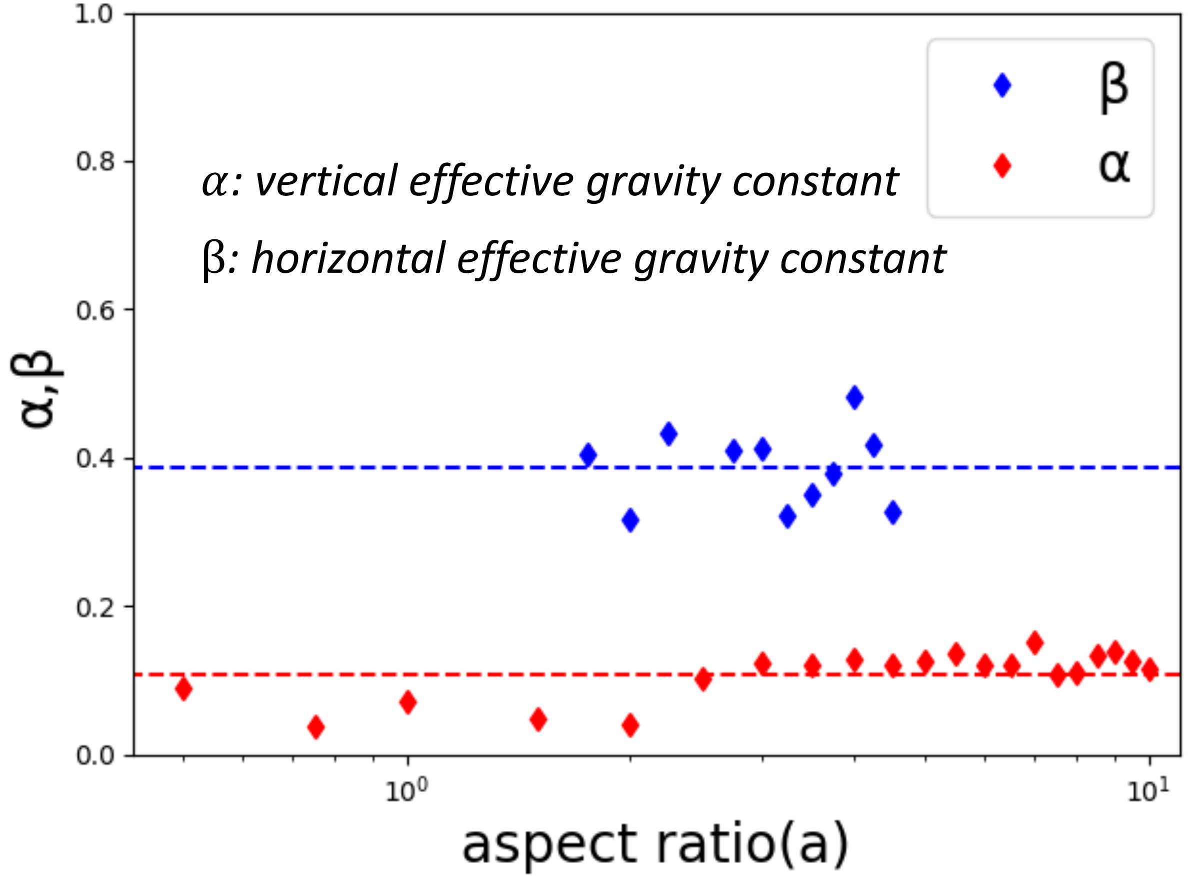
The data conforms to the uniformly accelerated motion curve during the acceleration phase.

Result: Vertical analysis



All data during the acceleration phase seem to collapse on the uniformly accelerated motion fit curve.

Result: α & β



α: vertical effective gravity constant

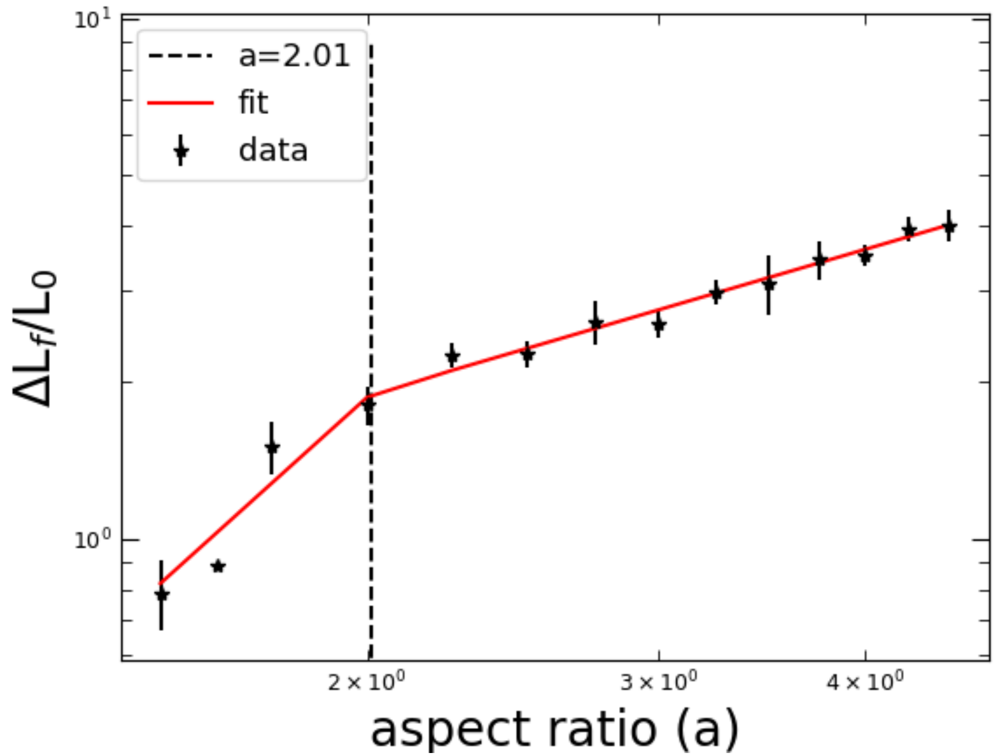
β: horizontal effective gravity constant

$$aspect\ ratio = \frac{H_0}{L_0}$$

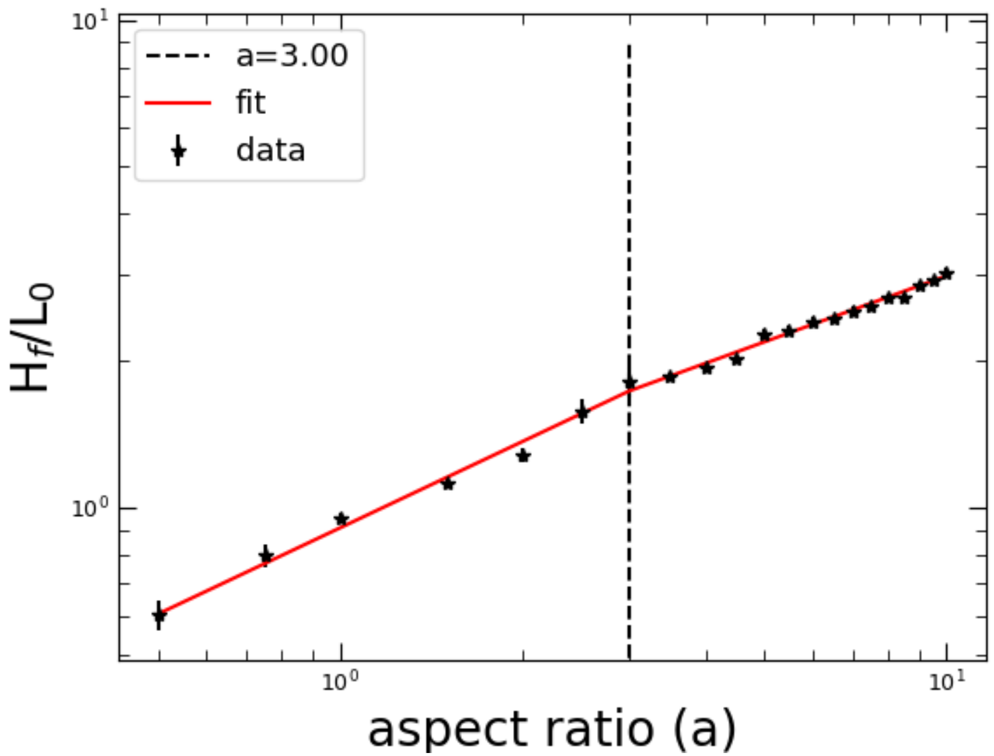
0.11g

0.39g

Result: Final height and Overflow length



$$\frac{\Delta L_f}{L_0} \cong \begin{cases} 0.26a^{2.86} & for\ a\ \leq 2.01 \\ 0.99a^{0.93} & for\ a\ \geq 2.01 \end{cases}$$



$$\frac{H_f}{L_0} \cong \begin{cases} 0.91a^{0.59} & for\ a\ \leq 3 \\ 1.1a^{0.45} & for\ a\ \geq 3 \end{cases}$$

Result

The turning point:

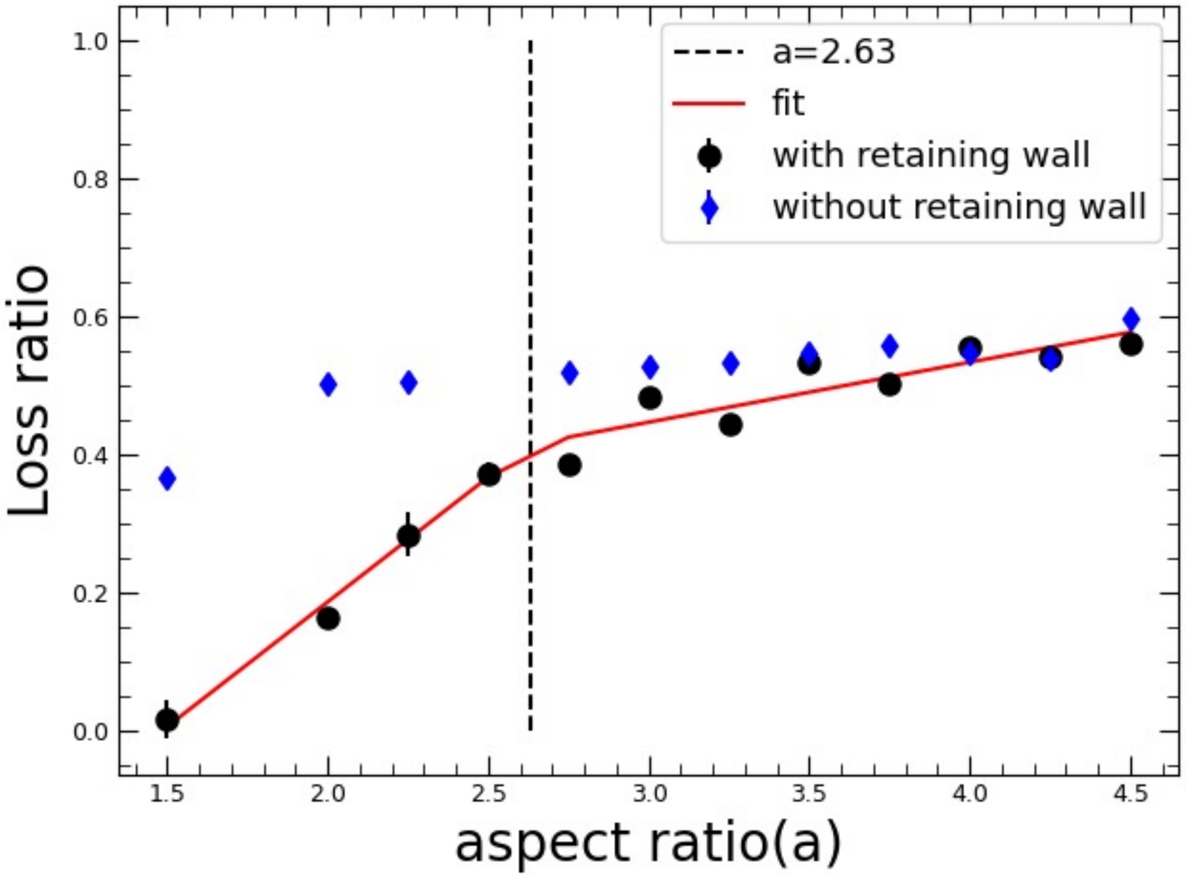
$aspect\ ratio = 1.5$

$aspect\ ratio = 4.5$

The slope changes from a straight line to a curve line as the aspect ratio increases.

Result: w/o retaining wall

- Area



$$aspect\ ratio = \frac{H_0}{L_0}$$

$$Retaining\ wall's\ height(H_{rw}) = 10cm$$

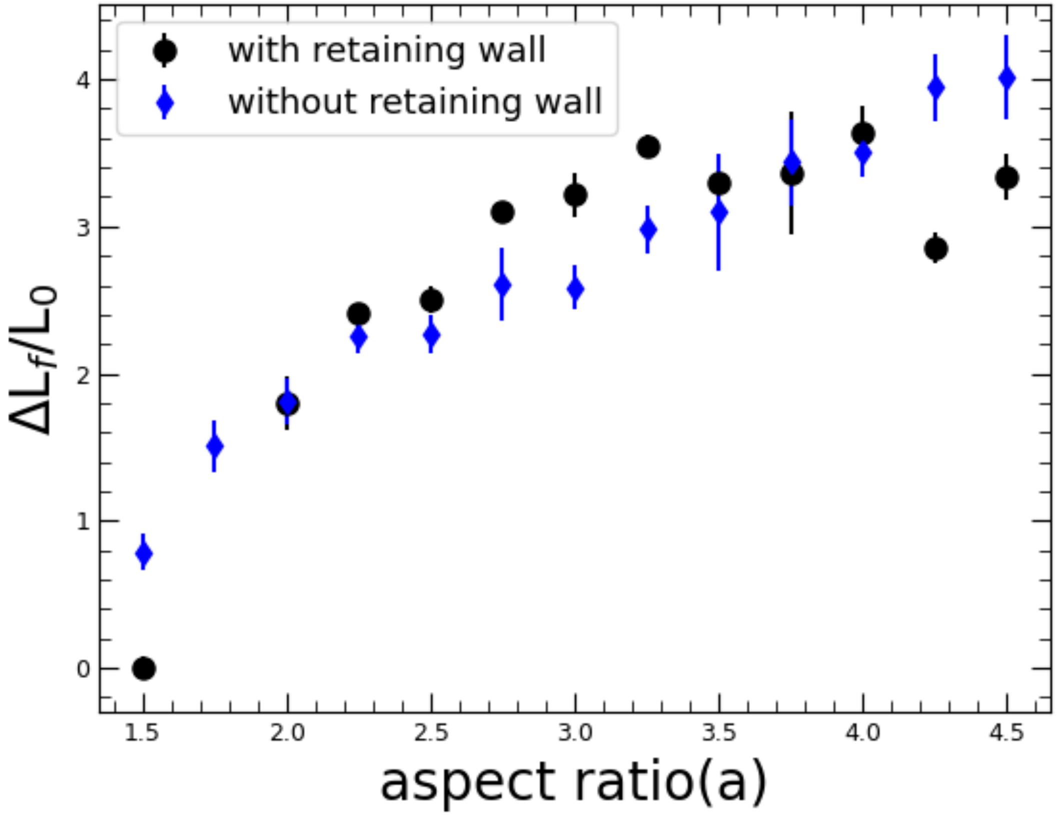
$$L_0 = 8.5cm$$

$$loss\ ratio = \frac{Green\ Area}{Red\ Area}$$

When aspect ratio is larger than 2.63, the use of retaining wall becomes invalid

Result: w/o retaining wall

- Overflow distance

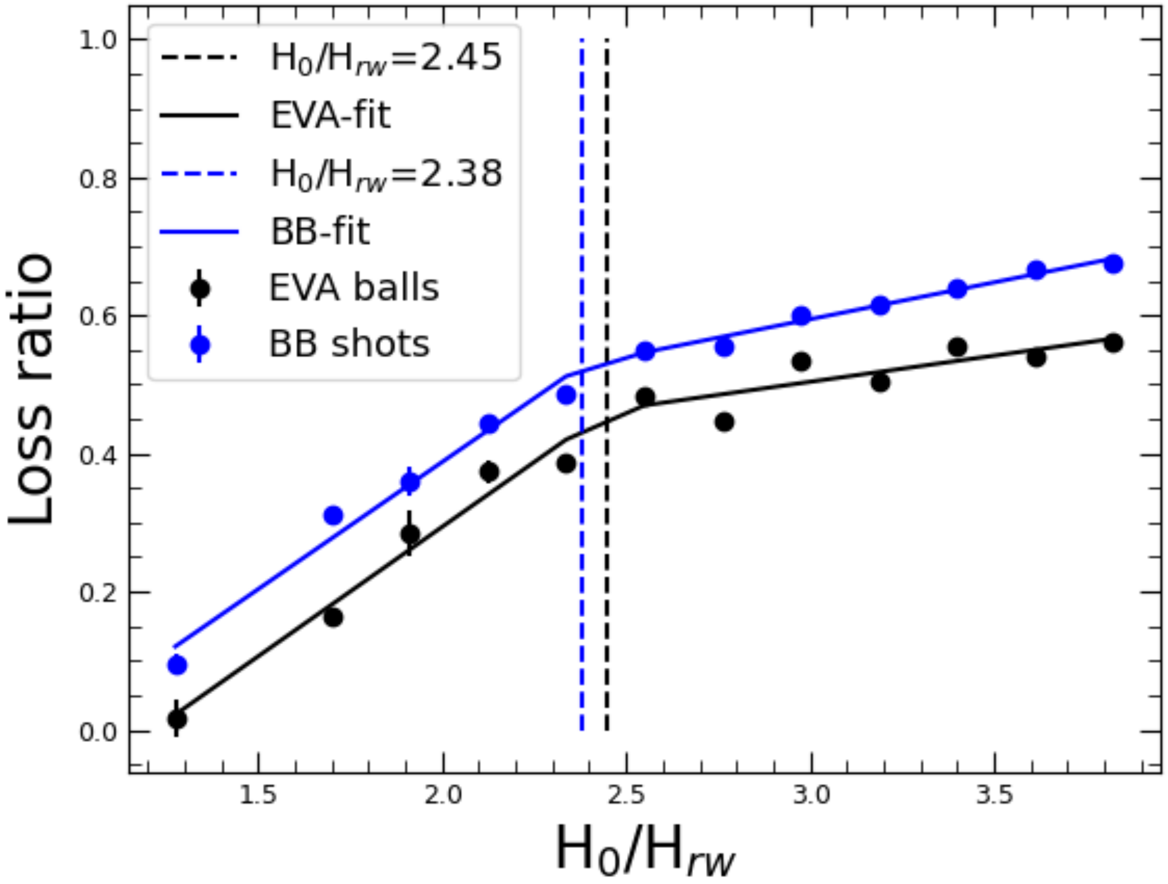


$$aspect\ ratio = \frac{H_0}{L_0}$$

As the result, we can see that the retaining wall doesn't have an obvious effect on the length that the EVA balls can run over.

Result: with retaining wall

- Different particles



	H_0/H_{rw} < turning point	H_0/H_{rw} > turning point
BB shots	0.37	0.11
EVA balls	0.37	0.08

The lost percentage of BB shots is always larger than EVA balls, because BB shots are more fluid.

Conclusion

1. *Uniformly accelerated motion:* *We confirm that the granular flow is uniformly accelerated motion, and the vertical and horizontal acceleration α and β are equal to 0.11 and 0.39, respectively.*

2. *Final height and overflow distance:* $\frac{H_f}{L_0} \cong \begin{cases} 0.91a^{0.59} & for\ a\ \leq 3 \\ 1.1a^{0.45} & for\ a\ \geq 3 \end{cases}, \frac{\Delta L_f}{L_0} \cong \begin{cases} 0.26a^{2.86} & for\ a\ \leq 2.01 \\ 0.99a^{0.93} & for\ a\ \geq 2.01 \end{cases}$

3. *Retaining wall:*
   - *Retaining wall is useless when aspect ratio exceeds 2.6.*
   - *It can reduce the loss of granular flow, but can't influence the overflow distance.*
   - *Due to different fluidity, the loss ratio of BB shots is higher than that of EVA balls.*