Chapter 4

Multi-scale modelling of dry granular flows

4.1 Introduction

The dynamics of a homogeneous granular flow involve at least three distinct scales: the *microscopic scale*, which is characterised by the contact between grains, the *meso-scale* that represents micro-structural effects such as grain rearrangement, and the *macroscopic scale*, where geometric correlations can be observed (see Figure 4.1). Conventionally, granular flows are modelled as a continuum because they exhibit many collective phenomena. However, on a grain scale, the granular materials exhibit complex solid-like and/or fluid-like behaviour.Recent studies, however, suggest that a continuum law may be unable to capture the effect of inhomogeneities at the grain scale level, such as orientation of force chains, which are micro-structural effects. Discrete element methods (DEM) are capable of simulating these micro-structural effects, however they are computationally expensive. In the present study, a multi-scale approach is adopted, using both DEM and continuum techniques, to better understand the rheology of granular flows and the limitations of continuum models.

4.2 Granular column collapse

The collapse of a granular column on a horizontal surface is a simple case of granular flow, however a proper model that describes the flow dynamics is still lacking. Granular flow is modelled as a frictional dissipation process in continuum mechanics but studies showing the lack of influence of inter-particle friction on the energy dissipation and spreading dynamics is surprising. In the present study, the generalised interpolation material point method

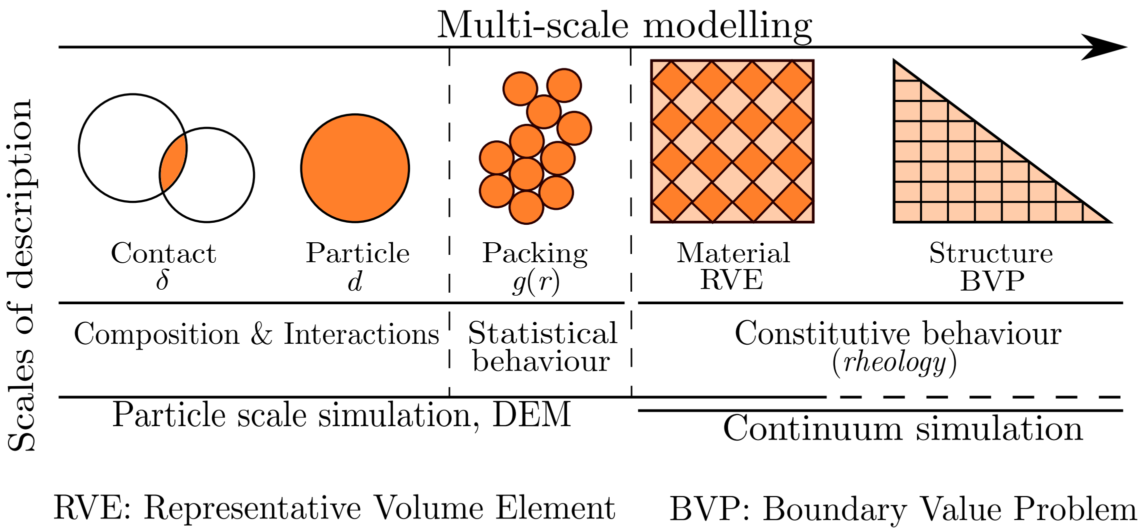

Figure 4.1 Multi-scale modelling of granular materials

(GIMPM), a hybrid Eulerian – Lagrangian approach, is implemented with Mohr-Coloumb failure criterion to describe the continuum behaviour of quasi-two dimensional collapse of granular columns. The granular column collapse is also simulated using DEM to understand the micro-mechanics of the flow.

Lajeunesse et al. (2005) performed axis-symmetric and plane strain tests on granular column collapse. Granular materials when released suddenly on a horizontal surface exhibit transient flow. The mechanism of flow initiation, spreading dynamics and energy dissipation are studied. The experimental configuration used by Lajeunesse et al. (2005) is shown in Figure 4.2. Granular material of mass 'M' was poured into a container to form a rectangular heap of length 'L_i', height 'H_i' and thickness 'W'. The internal friction angle and the wall friction between the wall and the glass beads measured by Lajeunesse et al. (2005) are listed in Table 4.1. The gate was then quickly removed to release the granular mass that spreads in the horizontal channel until it comes to rest. The final run-out distance 'L_f' and the collapsed height 'H_f' were measured. The run-out distance and collapse height were found to exhibit power law relation with the initial aspect ratio 'a' $(= H_i/L_i)$ of the column.

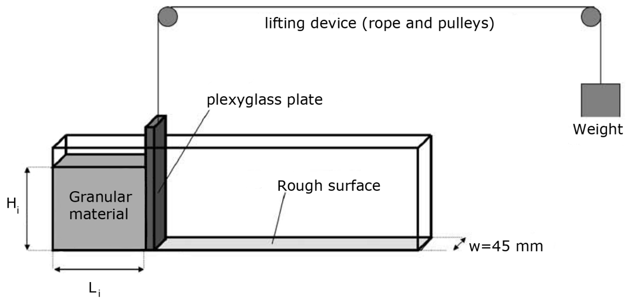

Figure 4.2 Schematic of experimental configuration for 2-D collapse in a rectangular channel, (Lajeunesse et al., 2005)

Table 4.1 Material properties, (Lajeunesse et al., 2005)

Parameter	**Value**
Material	Glass beads
Mean diameter of the glass beads	1.15 mm
Repose angle of glass beads	22 ± 0.5^o
Avalanche angle of glass beads	27.4 ± 0.5^o
Wall friction angle of glass beads	24.8 ± 0.2^o

References

Lajeunesse, E., Monnier, J. B., and Homsy, G. M. (2005). Granular slumping on a horizontal surface. *Physics of Fluids*, 17(10).