Impact behavior of dry granular flow

Supervisor: Prof. Charles W. W. Ng
Research students: Raymond P.H. Law

Introduction

- Different particle size of clean uniform sand affects the internal angle of friction. (eg. Palmer, 2003, Jarrett, 1991 & Lahlouh, 1995)
- The internal deformation of the flow material is related to the flow behavior. (Iverson, 1997)
- The flow behavior is expected to be related to the impact behavior.
- The impact behavior of clean uniform sand is therefore expected to depend on the particle size.

Modeling impact behavior

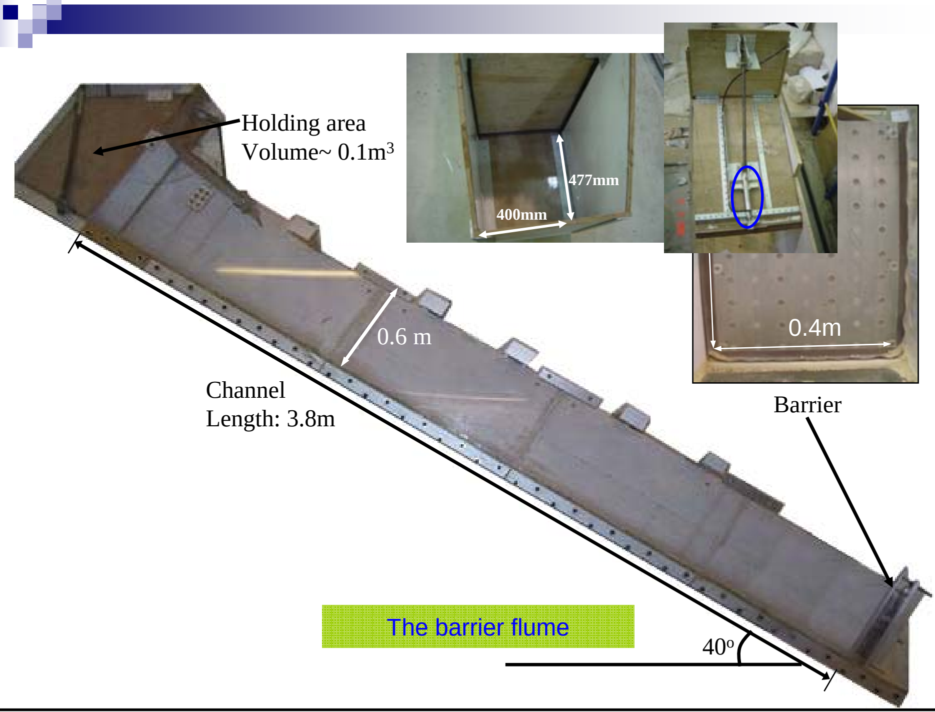
- Limitations of analytical solutions (eg. Daido, 1993; Lo, 2000)
  - Uncoupled analysis
  - Compatibility problem
- Limitations of finite difference modeling (eg. $FLAC^{2D}$, 2005)
  - Mesh distortion
  - Interface problem
- Advantages of discrete element modeling (DEM) (eg. PFC^{3D}, 2005)
  - Integrated flow and impact simulations
  - Mesh and interface problem avoided
  - Complicated model geometry allowed

Discrete element modeling

- Area based calculation versus volume based calculation
- No clear relation between the porosity value of a 2D and 3D assembly (Itasca, 2004)
- Comparatively lower porosity of 2D assembly (Deresiewicz, 1958)

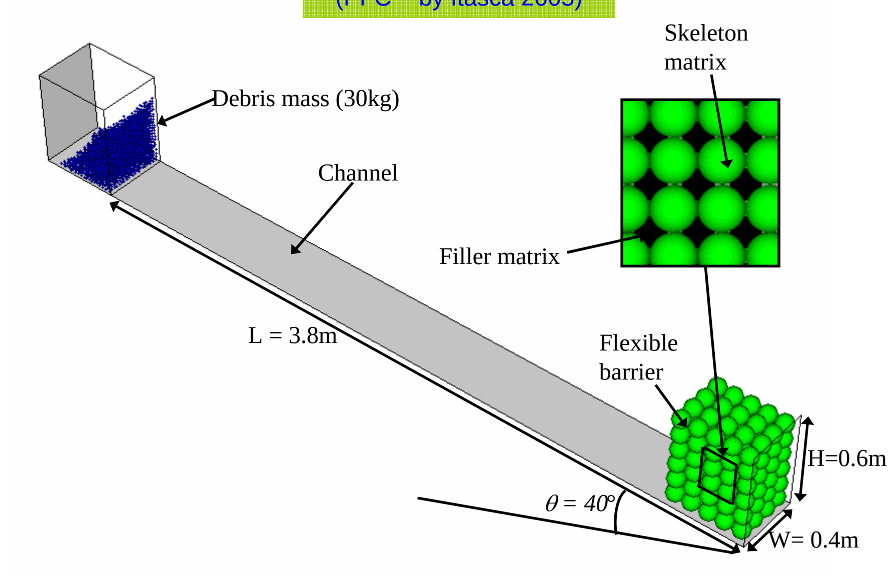
Objectives

- Analyzing the effect of particle size on impact force
- Studying the role of static load on impact force using DEM
- Comparing the computed results by 2D analysis and 3D analysis using DEM



The barrier flume

Particulate model
(PFC^{3D} by Itasca 2005)



Test plan

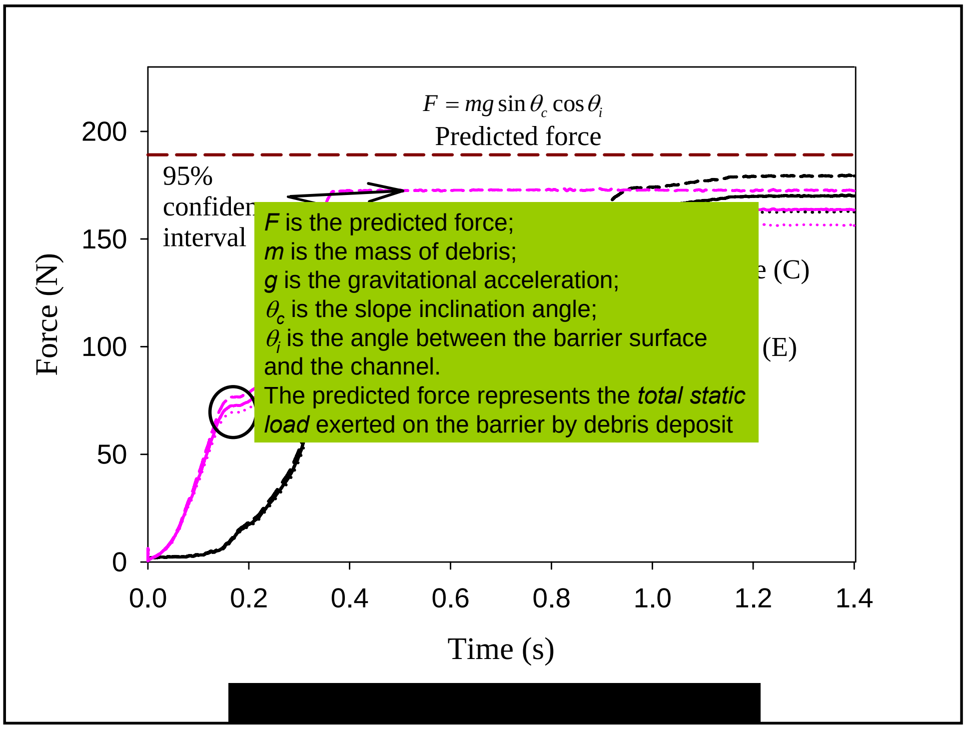
Flume model test

Series	material	barrier stiffness (N-m)	water content (%)	mass (kg)
1	LB sand[(1)] (fraction C)	29300	0	30
	LB sand (fraction E)	29300	0	30

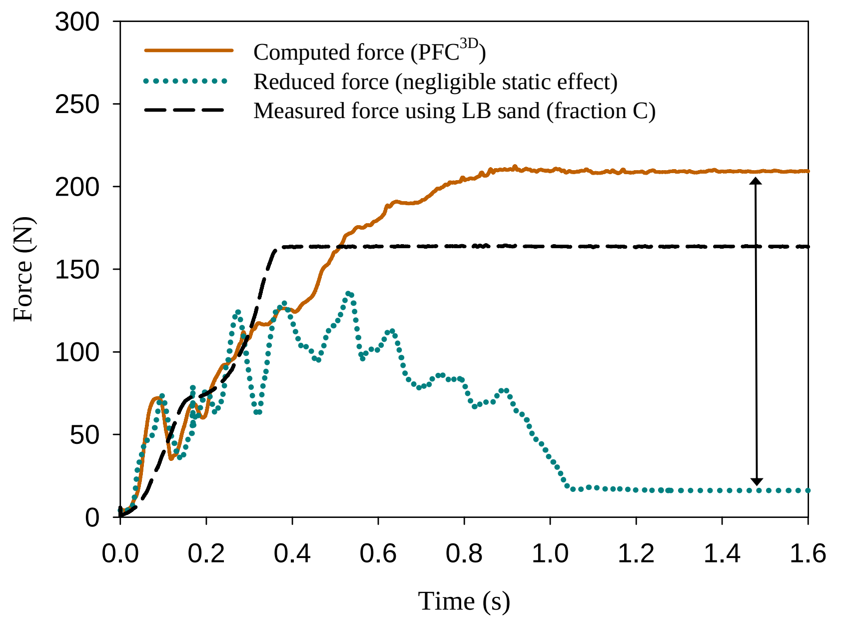
PFC

Series	barrier stiffness (N-m)	Remarks
2	29300	PFC^{3D}
	29300	Static load reduced, PFC^{3D}
3	Rigid	PFC^{3D}
	Rigid	PFC^{2D}

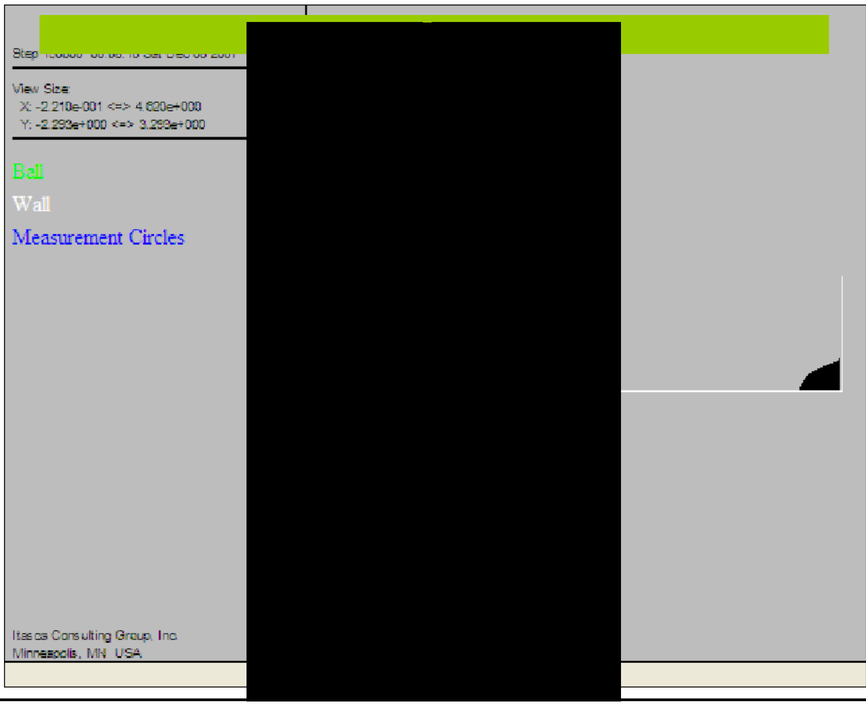
(1) : Leighton Buzzard sand

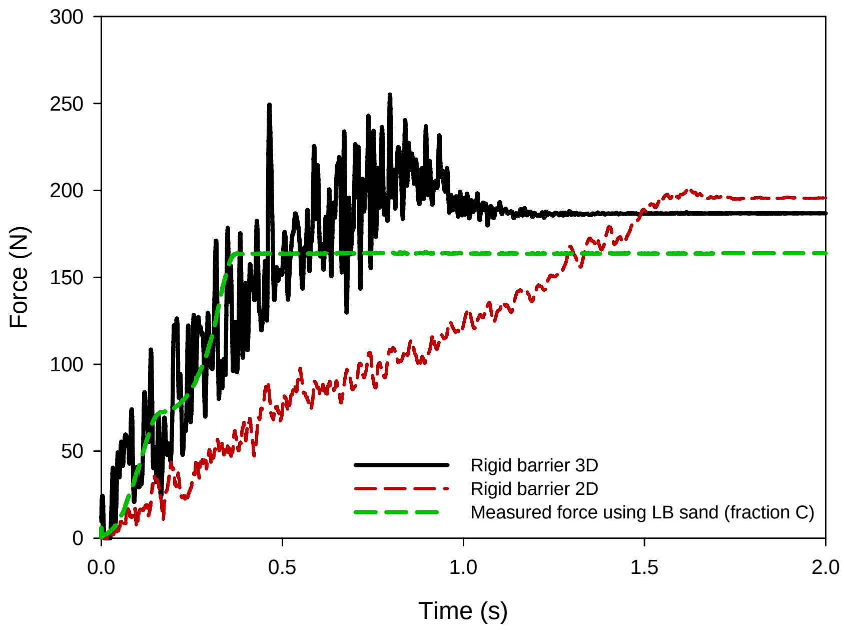


$F = mg\sin\theta_c\cos\theta_i$
Predicted force
95%
confiden
interval
e (C)
(E)
F is the predicted force;
m is the mass of debris;
g is the gravitational acceleration;
θ_c is the slope inclination angle;
θ_i is the angle between the barrier surface and the channel.
The predicted force represents the *total static load* exerted on the barrier by debris deposit
Force (N)
0
50
100
150
200
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Time (s)


Computed force (PFC3D)
Reduced force (negligible static effect)
Measured force using LB sand (fraction C)
Force (N)
300
250
200
150
100
50
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Time (s)

[redacted]


[redacted]
View Size:
X: -2.210e-001 <=> 4.620e+000
Y: -2.293e+000 <=> 3.293e+000
Ball
Wall
Measurement Circles
Itasca Consulting Group, Inc.
Minneapolis, MN USA



[redacted]

Conclusions

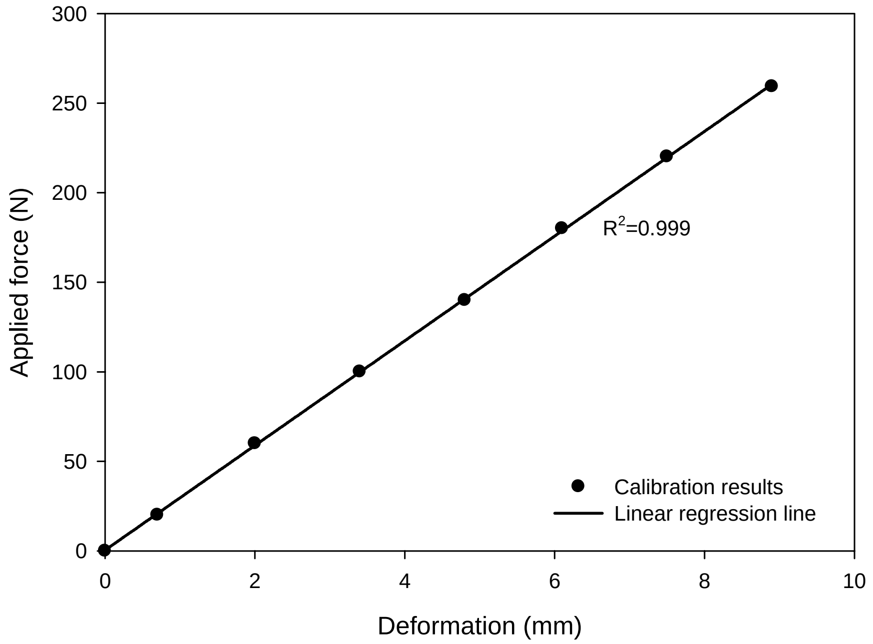
- Longer impact time for finer grained soil
- Progressive deposition by the impact of dry granular soil
- Increasing contributing of the static load in the course of impact
- Longer impact time for 2D than 3D analysis

Thank you

Appendix

Parameter	[redacted]	
Slope angle	[redacted]	
Length of the	[redacted]	
Stiffness of w	[redacted]	m m
Dimensions o	[redacted]	
Ball radius	[redacted]	
Number of ba	[redacted]	
Ball radius of	[redacted]	
Density of eac	[redacted]	g/m^3 /m^3
Mass of debris	[redacted]	
Ball stiffness	[redacted]	m N/m
Internal frictio	[redacted]	95)
Interface fricti	[redacted]	
Local dampin	[redacted]	
Viscous norm	[redacted]	
Viscous shear	[redacted]	

Parameter	[redacted]	
Slope angle	[redacted]	
Length of the	[redacted]	
Stiffness of w	[redacted]	m m
Dimensions c	[redacted]	
Ball radius	[redacted]	
Number of ba	[redacted]	
Density of ea	[redacted]	g/m^3
Mass of debri	[redacted]	
Ball stiffness	[redacted]	m
Internal fricti	[redacted]	nlouh, 1995)
Interface frict	[redacted]	
Local dampin	[redacted]	
Viscous norm	[redacted]	1985)
Viscous shear	[redacted]	1985)


Applied force (N)
300
250
200
150
100
50
0
0
2
4
6
8
10
Deformation (mm)
R^2=0.999
Calibration results
Linear regression line

[redacted]