Fluid Gravity

Two-phase Modelling of Blast Mitigation

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Introduction

- MOD project on "Mitigation Techniques for Explosives"
  - blast and fragment mitigation
  - Mitigant in contact with, or in close proximity to, explosive device
  - 2002 to present
- DSTL (Fort Halstead): experimental studies
- FGE (St Andrews): theoretical modelling
  - Chris Mellor, Richard Brown, Scott Cargill, Andrew Milne, Alec Milne, Aaron Longbottom

Aims of Project

- Understand both blast, fragment and combined blast/fragment systems
- Wide range of devices (from kilograms to tonnes)
- In terms of blast mitigation we are interested in:
  - Understanding basic physical processes involved
  - Reducing the blast effect
  - How blast process the mitigant
  - How this might affect fragment mitigation properties
- Mitigant design

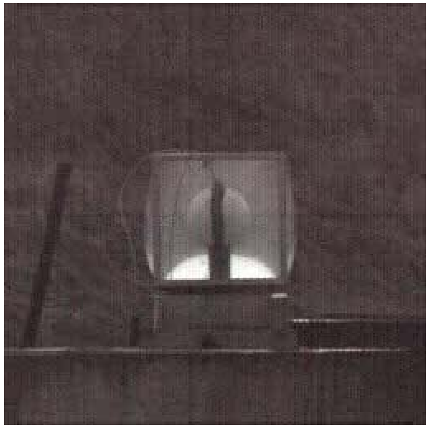
DSTL Experiments

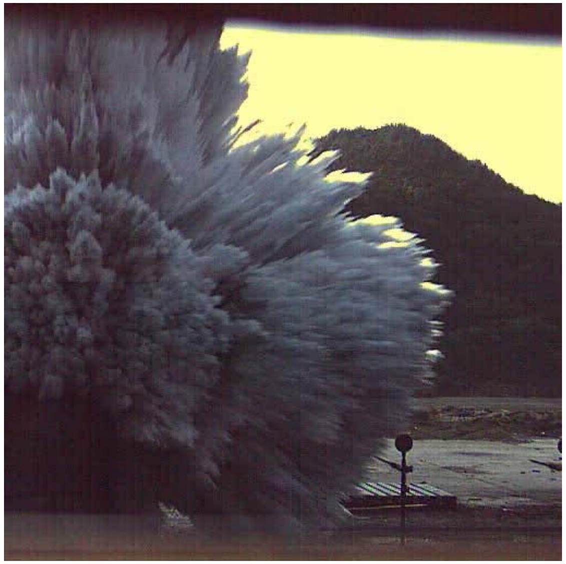
Fluid Gravity

- Current charge sizes 10g to 10kg
  - Spheres above ground or hemispheres on ground
- Granular or Liquid (droplet) mitigants
  - Generally a matrix of a component material in air
  - Continuum liquid → dispersed droplets
- Key characteristics investigated:
  - Different component materials
  - Porosity
  - Density
  - Thickness
  - Standoff
  - Charge size

DSTL Experiments

- 7.5kg PE4
- ~16cm depth of water
- Pressure gauges at 2m intervals out to 14m
- Gauges & movies can provide x-t plots for shock & particle cloud





Two-phase Theory

- Two-phases:
  - Solid particle/liquid droplets
  - background material/gas
- Set of continuum equations for each phase
- Phases interact through
  - drag (scales as particle diameter)
  - nozzling
  - heat conduction (scales as square of particle diameter)
  - burning/evaporation
- No longer hydrodynamic scaling (multiple length scales)

Fluid Gravity

Two-phase Equations

- Equation set based on work of Baer & Nunziato (1986)

Fluid Conservation Laws	Particle Conservation Laws
Mass	Mass
Momentum	Momentum
Energy	Energy
Stress Deviators	
Volume fraction	Volume fraction
Closure	Closure
Equation of State	Equation of State
Constitutive Model	Inter-particle Stress
Mass transfer	Mass transfer
Momentum transfer (drag)	Momentum transfer (drag)
Energy Transfer	Energy Transfer
	Burning Laws

Why Two-phase Theory?

Fluid Gravity

- Each phase has its own velocity, temperature and pressure
  - Phases can flow though each other and coexist with different state variables

- We are interested in
  - Granular mitigants composed of particles
  - Liquid mitigants that break up into droplets

- Particles/droplets accelerated/heated by explosive
  - Takes energy from system

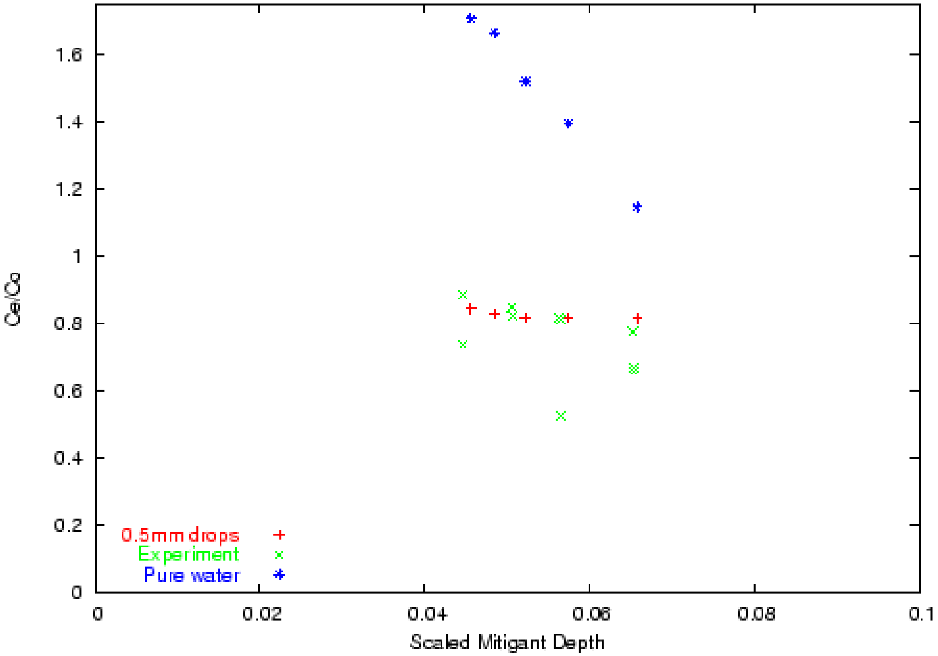
- Later slow and cool
  - Gives energy back to system

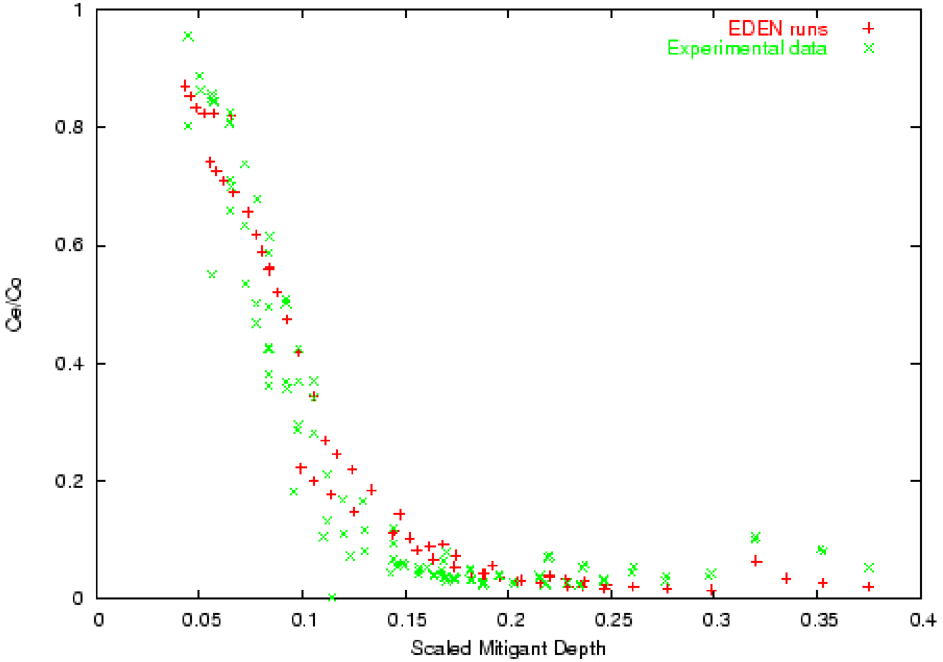
Two-phase vs. Continuum Modelling

Fluid Gravity

- Water layer in continuum (pure water) acts as piston
  - Can increase pressure over that of bare charge case

- Two-phase (droplet) model allows flows through mitigant/air
  - Gives good agreement with experiment





Summary

- Investigating blast mitigation with mitigant in close proximity to explosive
- Extensive experimental program by DSTL studying key characteristics of mitigant systems
- FGE has undertaken two-phase modelling of the mitigants
- Two-phase theory gives good agreement for granular and liquid (droplet) based mitigants
- Understanding underlying physical process' should enable design of new mitigant systems