Soil Properties Influence on Land Mine Blast Effects

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Agenda

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Land Mines

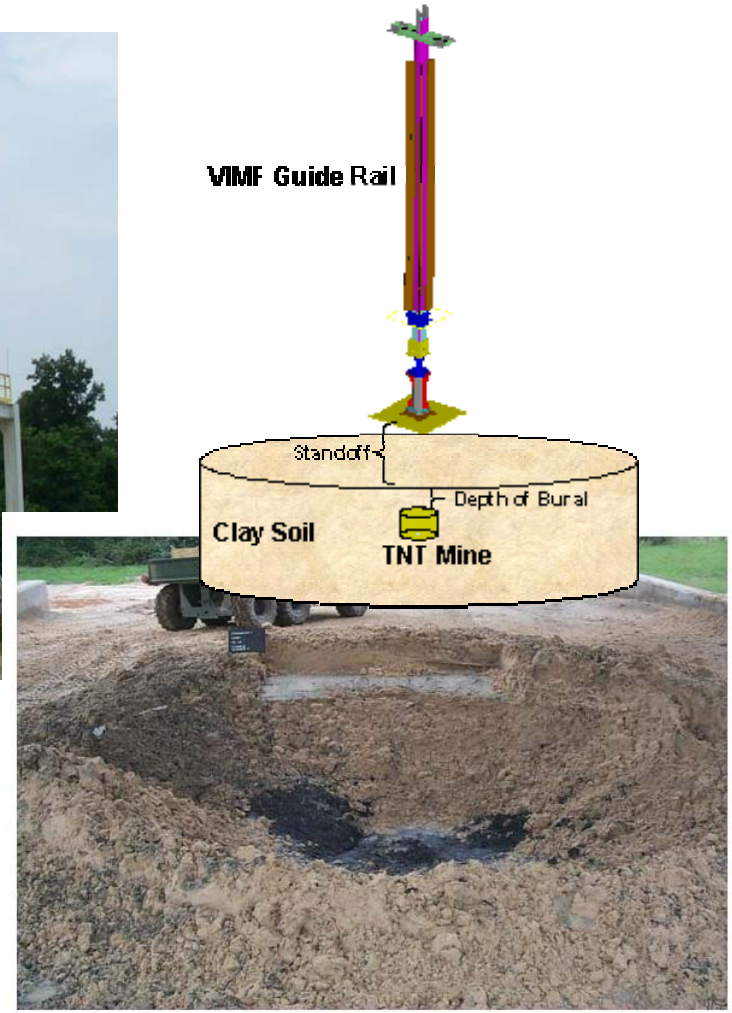
- Flat, typically circular
- Varied explosives
- Booster charges possible
- Surface-laid or buried
- Blast directed upward
- Tank loss rates > 50% since WW II

Anti-tank mine exposed. Photo courtesy of Afghan Technical Consultants, Peshawar. http://www.mech.uwa.edu.au/jpt/demining/countries/afghan/minefields-afghan.html

Vertical Impulse Measurement Fixture (VIMF)

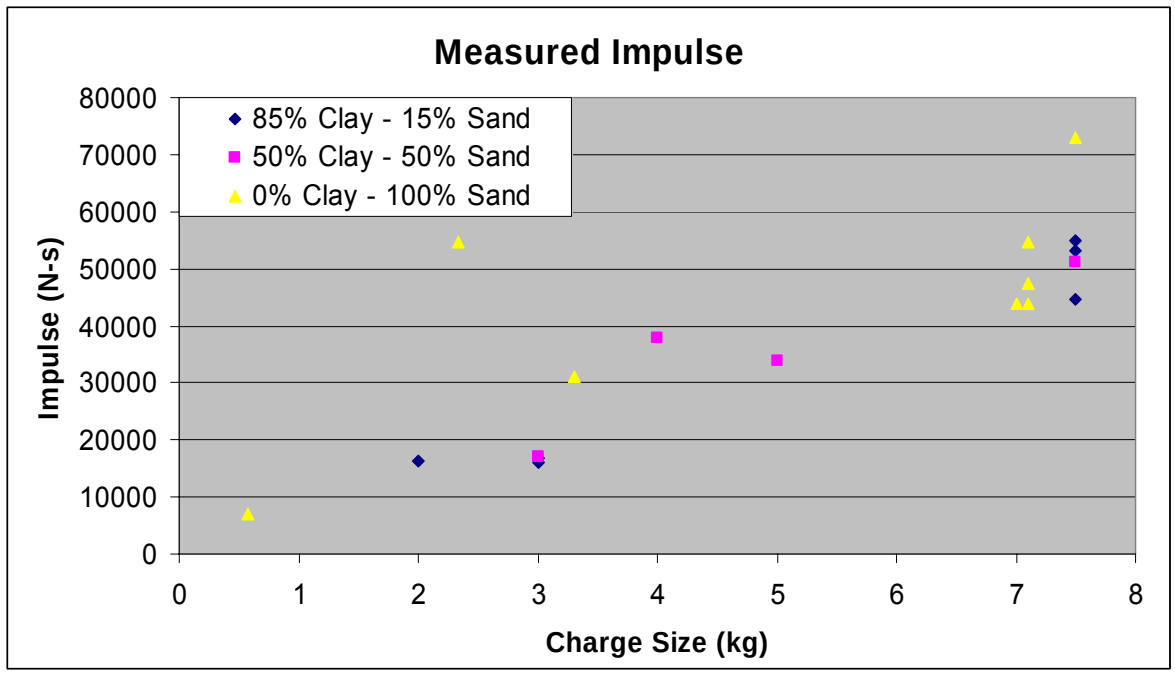
- Full scale experiments
- Witness plate on guide rail
- Measure vertical displacement
- Can calculate impulse

$$I = M \cdot [2 \cdot g \cdot d]^{1/2}$$



Impulse vs Charge Size

- Affected by:
  - Standoff distance
  - Moisture content
  - Soil type

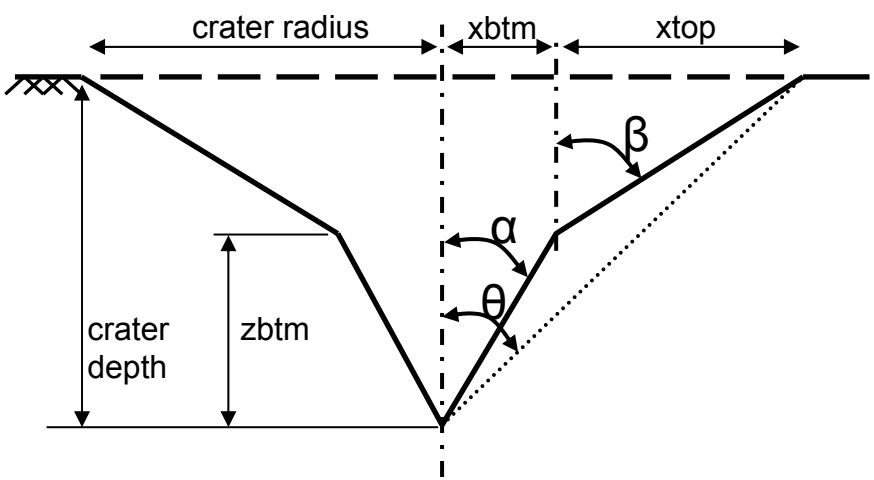


Soil Properties

- Soil Type
  - Fine grained (clays and silts)
  - Coarse grained (sands and gravels)
- Voids
  - Air: removed by mechanical compaction
  - Water: expelled over time – consolidation
  - Moisture content
- Traditional strength parameters
  - Cohesion
  - Friction angle
- Non-homogeneous, non-isotropic, non-linear

Geometry and Characteristic Angle

- Crater forms as a result of blast
- Soil type influences shape of crater
  - High clay content—steep crater walls
  - High sand content—shallower walls



Soil Type	Crater Angle
% C / % S	(deg)
85 / 15	56.35
50 / 50	61.17
0 / 100	65.18

Flyrock Model

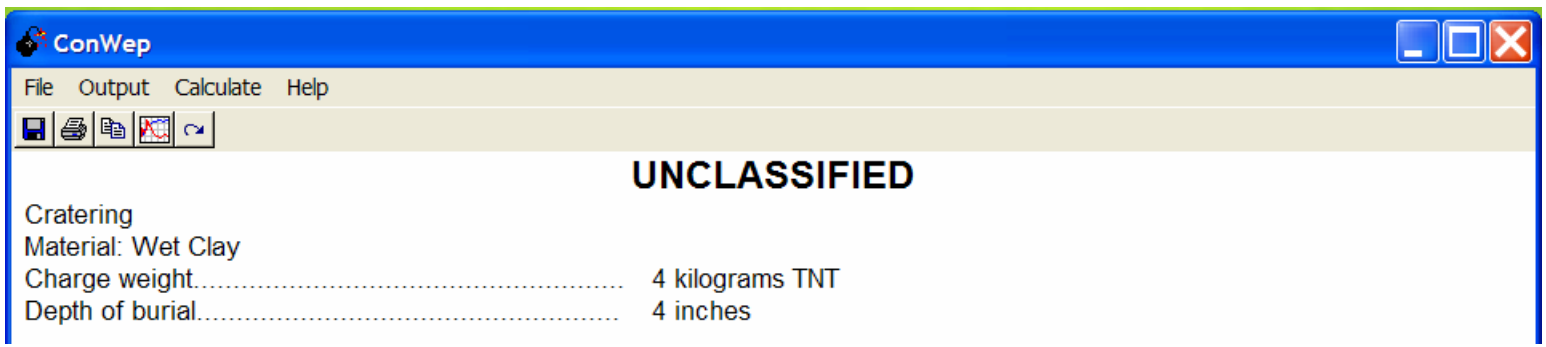
- Based on mining industry
- Predicts how far and fast a boulder will fly
- Inputs:
  - Charge Size
  - Distance to target
  - Area of boulder
- Extrapolate to soil grains to predict impulse

Flyrock Model (2)

- Assumptions:
  - Spherical, uniform grain size
  - Bare explosive only
  - Distance to charge is standoff distance only
- Total Impulse = # Grains * Grain Impulse
- # Grains estimated by crater volume
- Grain Impulse is proportional to
  - Charge size
  - Distance from charge to target
  - Area of grain

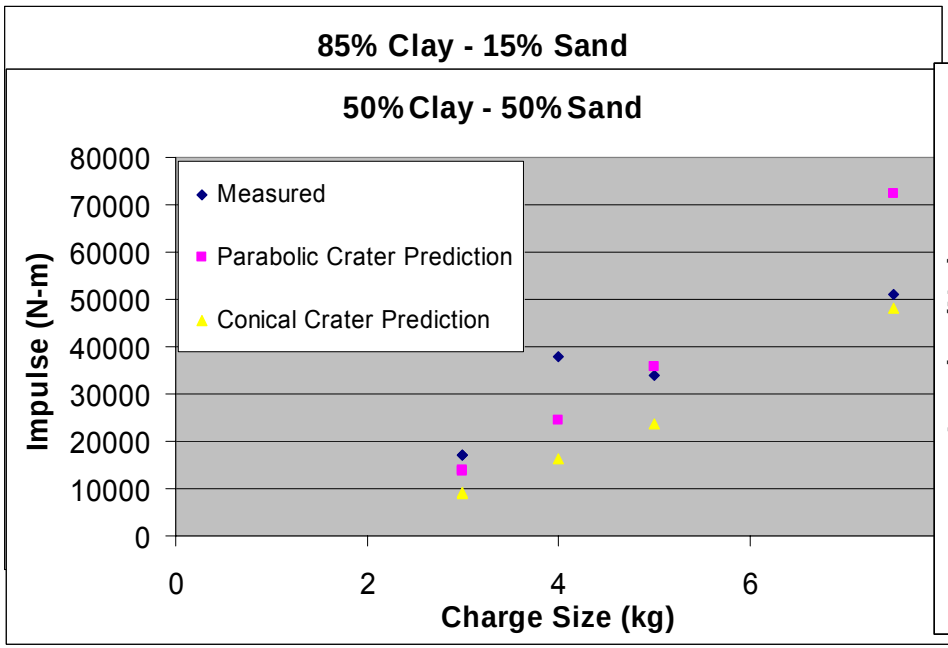
Crater Prediction

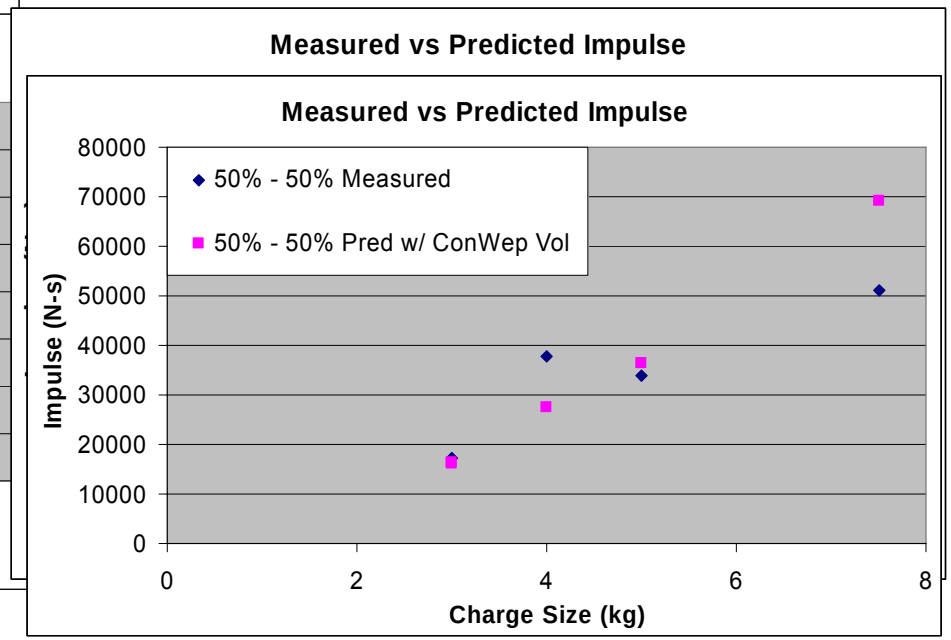
- Must be able to predict crater size to estimate # Grains
- Allows calculation of volume of soil and number of soil grains ejected
- ConWep software with “best” soil fit



Crater + Flyrock

- Comparable results to known crater cases





Model Limitations

- Account for soil conditions:
  - Moisture content
  - Grain size variability and shape
  - Better soil type models
  - Depth of burial
- Witness plate location and ejecta dispersion
- Explosive proportionality constants
- Bare explosives only

Conclusions

- Simple, conservative model
- Soil-blast interaction needs more development
  - Account for explosive variations
  - Account for soil properties
  - Charge configuration and placement
- Tool to help designers improve survivability of crews and hulls

Resources

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