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A Mathematical Model for the Acoustic and Seismic Properties of the Landmine Detection Problem

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Outline of Topics

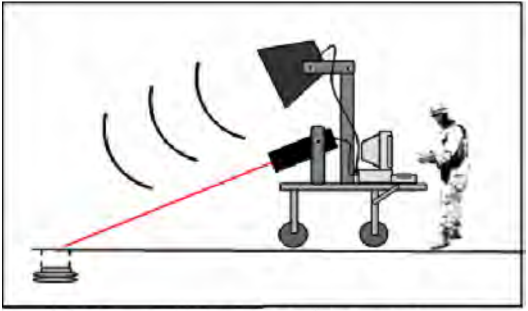
1. Introduction to the non-metallic landmine problem
2. Current research in acoustic to seismic landmine detection
3. Analytical Model
4. COMSOL® Comparison
5. Future Work and Acknowledgements

Introduction

- Non-metallic landmine detection problem originates from World War II
- Limited methods available to solve the non-metallic landmine problem
  - Explosive Vapor Techniques
  - Acoustic to Seismic Technology

Sabatier's Model

- Dr. James Sabatier's experimental research at the National Center for Physical Acoustics



Sabatier's Proposed Seismic to Acoustic Landmine Detection Apparatus

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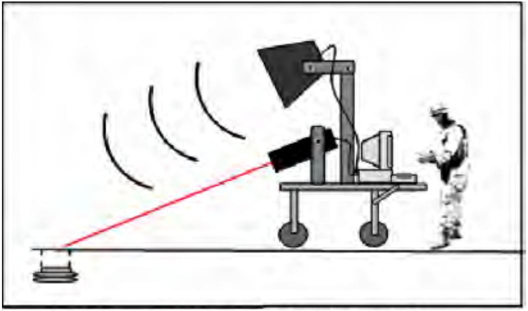
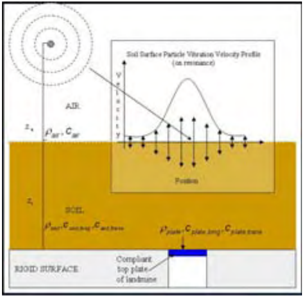


Sabatier's Proposed Seismic to Acoustic Landmine Detection Apparatus

- Landmine resonances occur when the landmine vibrates at maximum amplitude at a particular frequency, known as the resonant frequency.

Physical Representation of Sabatier's Experiments

- Understanding the physical processes in Sabatier's experiments is necessary for creating the mathematical models.



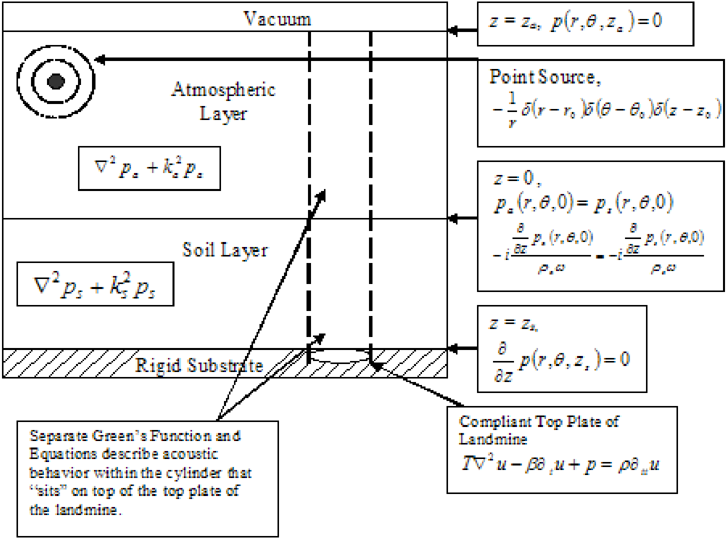
- PROJECT GOAL: Theoretically predict the resonances and soil surface velocity profiles obtained by Sabatier

Important Notes

- Loudspeaker is represented as a point source.
- Maximum soil displacement occurs over the mine at resonant frequencies.
- Simplified damping was applied to the system, and other losses were ignored.
- Soil was modeled as an effective fluid.
- Solved the linear, time harmonic, acoustic wave equation: $\nabla^2 p = -k^2 p$.

Analytical Model

The Membrane Problem



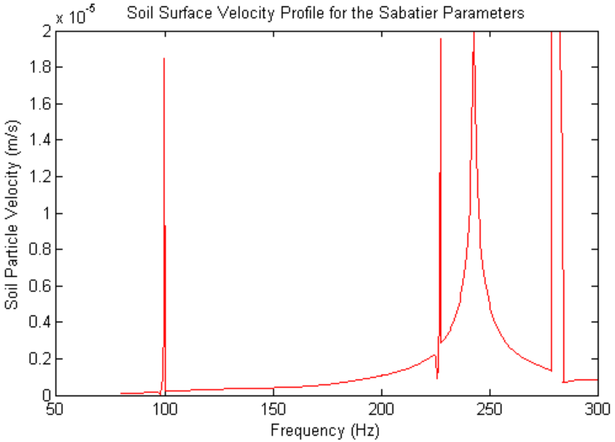
Analytical Model

The Analytical Solution

- The equation describing the soil particle velocity at a point (r, θ, z) is

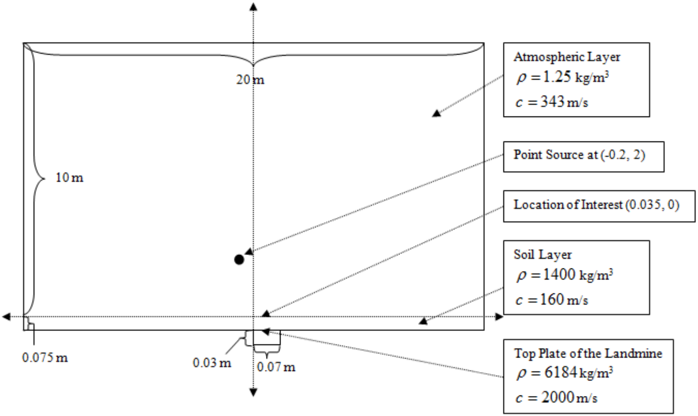
$$w = \frac{1}{i\omega\rho_a} \sum_{m=0}^{\infty} \sum_{n=1}^{\infty} J_m\left(\sqrt{\zeta_{mn}}r\right) A_{mn} \cos\left(m\theta\right) \phi'_{mn,air}\left(z\right)$$

Analytical Model
Soil Surface Velocity Plot



COMSOL®

Comsol Implementation Diagram



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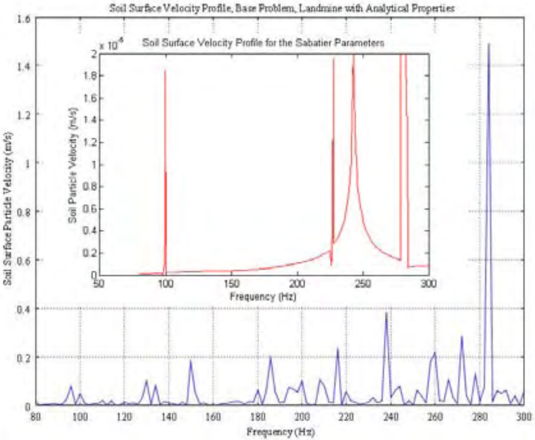
Comsol Prediction and Comparison



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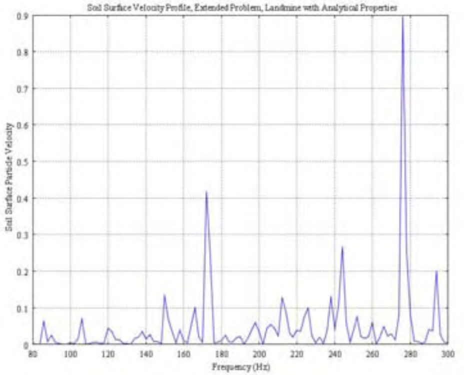
Comsol Prediction for the Extended Model



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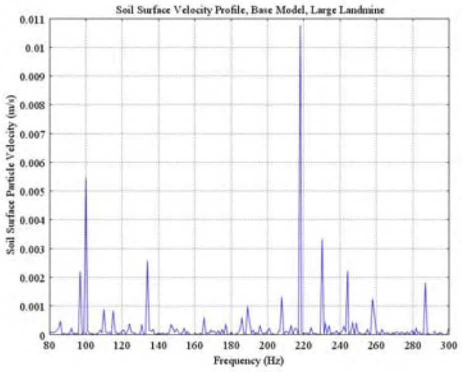
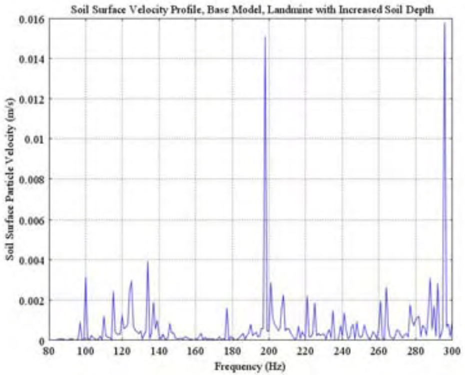
Extension of the Base Model



COMSOL®

Extension of the Base Model



Future Work

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  - Landmine property limitations - smallest size for detection, density, tension
  - Soil limitations - depth, layering, porosity, effective fluid model
- Possibility of obtaining an analytical solution or another numerical solution for the extended problem.

Acknowledgements

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