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In-Situ Subsurface Density Estimations using a Seismic Technique

By

Christoffel Johannes Stephanus Fourie

Submitted in partial fulfillment of the requirements for the degree Philosophiae Doctor (PhD) in Exploration Geophysics in the Faculty of Natural and Agricultural Sciences, University of Pretoria

Pretoria

September 2007

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I, C.J.S. Fourie hereby declare that this thesis "In-Situ Subsurface Density Estimations using a Seismic Technique", which I hereby submit for the degree PHd (Exploration Geophysics) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution - Regulation 57.4(e)

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ABSTRACT

A new geophysical method was developed to satisfy a need for in-situ density measurements. Various situations, such as a gravity dam wall requires that density measurements should be done without damage to the structure. The sample volume should also not be that large in order to be sensitive enough for variations.

This method measures the in-situ density of the weathered layer and other man made structures, using seismic waves in three directions. The seismic waves utilized are P-waves and S-waves. It is however surface waves that are treated like body waves because they do not separate at this shallow depth.

These waves are very sensitive to the attenuation factor, which is in turn sensitive to certain physical properties of the propagation medium. This factor is utilsed when the multi layer problem is encountered. The maximum depth of exploration is 2-5m and depends solely on the seismic skin depth.

This method utilses a large base plate. The source is a large sledge hammer and shots are done at each side of the base plate. Different dominant frequencies are identified and used to calculate the densities of the layers associated with that specific frequency. The velocities of the subsurface are determined by small seismic refraction surveys.

The method will find application mainly in the civil and engineering geology fields. The main application will be to determine subsurface densities and small movement elasticity modulli for engineers to aid in obtaining adequate design parameters.

Case studies on three different geologic environments are presented. The results indicate that this method will be useful, although certain modifications are recommended to make this method even faster and more user friendly.

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CHAPTER 1 – Review of existing density determinations

CHAPTER 4 – Equipment and experimental work

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List of Symbols

SYMBOL	EXPLANATION	SYMBOL	EXPLANATION
F_p	P - wave force	F_s	S - wave force
k_p	P - wave spring constant	k_s	S - wave spring constant
x_p	P - wave displacement	x_s	S - wave displacement
M_{0p}	Excited Groundmass	M_{0s}	Excited Groundmass
$\ddot{x}_p$	P-wave acceleration	$\ddot{x}_s$	S-wave acceleration
ω_{0p}	P-wave Initial Angular Frequency	ω_{0s}	S-wave Initial Angular Frequency
Δm	Additional mass	ω_{1s}	Angular Frequency of the S - wave
ω_{1p}	Angular Frequency of the P - wave	h_s	Depth below base plate
A	Area of influence	V_{0s}	Volume of excited mass by S - wave
L	Length of base plate	b_s	Damping factor of the S - wave
h_p	Depth below base plate	V_s	Velocity of the S - wave
α	Influence angle	ε_s	S – wave attenuation
V_{0p}	Volume of excited mass by P - wave	Q_s	S – wave quality factor
b_p	Damping factor of the P-wave	A_{0s}	Initial S - wave amplitude
V_p	Velocity of the P-wave	$A_s(\varepsilon)$	Decayed S - wave amplitude
ε_p	P – wave attenuation	E_s	S - wave energy
Q_p	P – wave quality factor	δ_s	S – wave logarithmic decrement
A_{0p}	Initial P - wave amplitude	f_s	S – wave frequency
$A_p(\varepsilon)$	Decayed P - wave amplitude	λ_s	S - Wave length
E_p	P - wave energy	E_{ks}	S - wave kinetic energy
δ_p	P – wave logarithmic decrement	ρ_{0s}	Horizontal density
f_p	P – wave frequency		
λ_p	P-Wave length		
E_{kp}	P - wave kinetic energy		
ρ_{0p}	Vertical density		

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