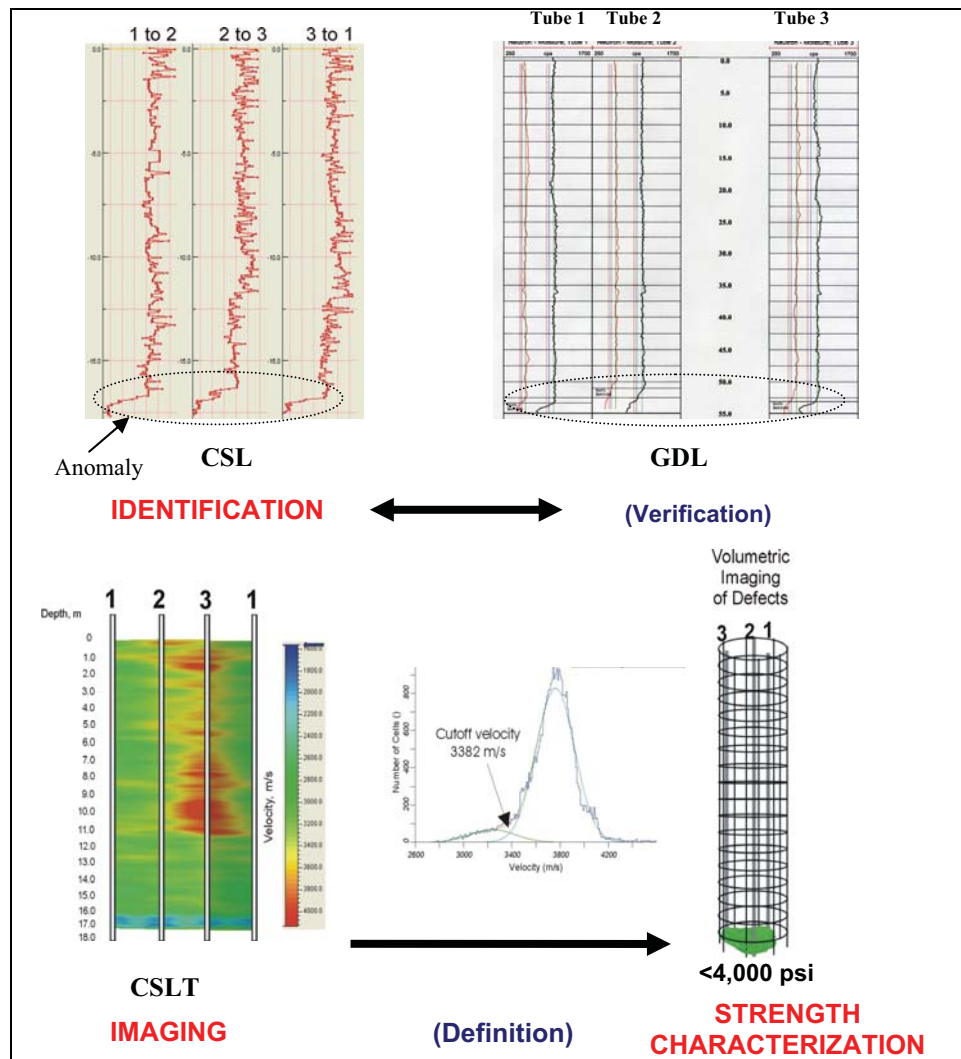


# DRILLED SHAFT FOUNDATION DEFECTS

## Identification, Imaging, and Characterization

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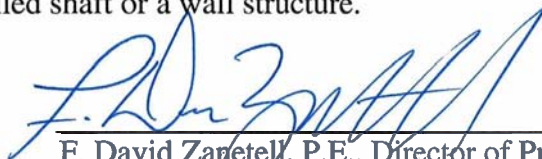


Central Federal Lands Highway Division  
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Lakewood, CO 80228

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Specifically, this report addresses what constitutes a defect in a newly constructed drilled shaft foundation and how to relate observed defects in a geophysical velocity tomogram to engineering strength information for integrity assessment. This study, therefore, closes the present decision making gap by the foundation engineer in deciding to accept, correct (remediate), or reject a given drilled shaft or a wall structure.



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F. David Zanetell, P.E., Director of Project Delivery  
Federal Highway Administration  
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16. Abstract This report addresses two key issues needed by the foundation engineer to assess the structural integrity of drilled shaft, or other concrete structures that contain access tubes; specifically: <ul style="list-style-type: none"> <li>a) What constitutes a defect in a drilled shaft?; and,</li> <li>b) How to relate observed defect in a velocity tomogram to engineering strength information?</li> </ul> <p>This study was conducted based on the development of a three-step approach:</p> <ul style="list-style-type: none"> <li>1) <i>Anomaly Identification and Independent Verification</i> - This step allows the engineer to identify and independently verify suspected “<b>anomalies</b>” in drilled shafts. It is concluded that both crosshole sonic logging (CSL) and gamma-gamma density logging (GDL) must be used. For <u>velocity imaging</u> of the shaft's interior, three-dimensional crosshole sonic logging tomography (CSLT) is required.</li> <li>2) <i>Defect Definition</i> – A statistical approach is presented to define a cut-off velocity to separate CSLT velocity distribution of sound concrete from the velocity distribution of anomalous concrete. The cut-off velocity is then used to volumetrically image a “<b>defect</b>” volume.</li> <li>3) <i>Defect Characterization</i> – Finally, changes in velocity values in the defect volume is correlated to changes in concrete strength and a 3-D <u>strength image</u> is developed for integrity assessment by the engineer. The velocity-strength correlation is developed in the laboratory using cylinders with the same design mix as the shaft and allowing for maturity.</li> </ul> <p>Therefore, this study proposes a complete analysis and technical information to assist the foundation engineer and owner agencies in deciding to accept, remediate, or reject a given shaft or a wall structure.</p>					
17. Key Words Concrete Strength, Crosshole Sonic Logging (CSL), Defects, Drilled Shaft Foundations, Engineering Properties of Concrete, Integrity Testing, Gamma- Gamma Density Logging, Maturity, Nondestructive Testing (NDT), Temperature Monitoring, Tomography			18. Distribution Statement  No restriction. This document is available to the public from the sponsoring agency at the website <a href="http://www.cflhd.gov">http://www.cflhd.gov</a> .		
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<b>SI* (MODERN METRIC) CONVERSION FACTORS</b>				
<b>APPROXIMATE CONVERSIONS TO SI UNITS</b>				
<b>Symbol</b>	<b>When You Know</b>	<b>Multiply By</b>	<b>To Find</b>	<b>Symbol</b>
<b>LENGTH</b>				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
<b>AREA</b>				
in <sup>2</sup>	square inches	645.2	square millimeters	mm <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yard	0.836	square meters	m <sup>2</sup>
ac	acres	0.405	hectares	ha
mi <sup>2</sup>	square miles	2.59	square kilometers	km <sup>2</sup>
<b>VOLUME</b>				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft <sup>3</sup>	cubic feet	0.028	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	cubic meters	m <sup>3</sup>
NOTE: volumes greater than 1000 L shall be shown in m <sup>3</sup>				
<b>MASS</b>				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
<b>TEMPERATURE (exact degrees)</b>				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
<b>ILLUMINATION</b>				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m <sup>2</sup>	cd/m <sup>2</sup>
<b>FORCE and PRESSURE or STRESS</b>				
lbf	poundforce	4.45	newtons	N
lbf/in <sup>2</sup>	poundforce per square inch	6.89	kilopascals	kPa
<b>APPROXIMATE CONVERSIONS FROM SI UNITS</b>				
<b>Symbol</b>	<b>When You Know</b>	<b>Multiply By</b>	<b>To Find</b>	<b>Symbol</b>
<b>LENGTH</b>				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
<b>AREA</b>				
mm <sup>2</sup>	square millimeters	0.0016	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	10.764	square feet	ft <sup>2</sup>
m <sup>2</sup>	square meters	1.195	square yards	yd <sup>2</sup>
ha	hectares	2.47	acres	ac
km <sup>2</sup>	square kilometers	0.386	square miles	mi <sup>2</sup>
<b>VOLUME</b>				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m <sup>3</sup>	cubic meters	35.314	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.307	cubic yards	yd <sup>3</sup>
<b>MASS</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
<b>TEMPERATURE (exact degrees)</b>				
°C	Celsius	1.8C+32	Fahrenheit	°F
<b>ILLUMINATION</b>				
lx	lux	0.0929	foot-candles	fc
cd/m <sup>2</sup>	candela/m <sup>2</sup>	0.2919	foot-Lamberts	fl
<b>FORCE and PRESSURE or STRESS</b>				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in <sup>2</sup>

\*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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