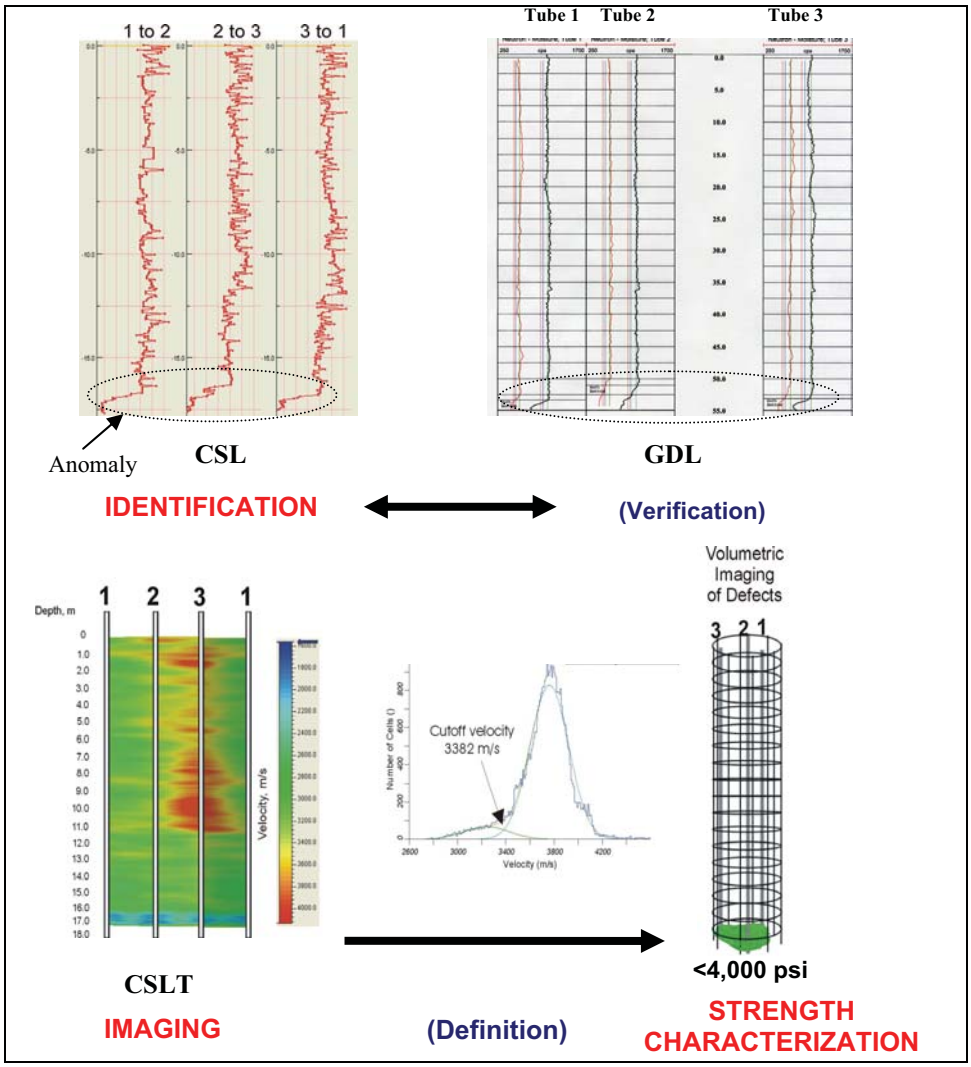
DRILLED SHAFT FOUNDATION DEFECTS
Identification, Imaging, and Characterization

Publication No. FHWA-CFL/TD-05-007 **October 2005**



U.S. Department of Transportation
Federal Highway Administration

Federal Lands Highway
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Central Federal Lands Highway Division
12300 West Dakota Avenue
Lakewood, CO 80228

FOREWORD

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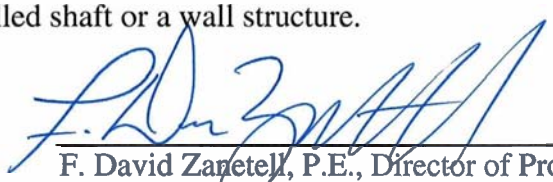
Specifically, this report addresses what constitutes a defect in a newly constructed drilled shaft foundation and how to relate observed defects in a geophysical velocity tomogram to engineering strength information for integrity assessment. This study, therefore, closes the present decision making gap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



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Technical Report Documentation Page

1. Report No.	2. Government Accession No	3. Recipient's Catalog No
FHWA-CFL/TD-05-003		

4. Title and Subtitle	5. Report Date
Defects in Drilled Shaft Foundations: Identification, Imaging, and Characterization	March 2005
	6. Performing Organization Code

7. Authors	8. Performing Organization Report No.
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9. Performing Organization Name and Address	10. Work Unit No.
Blackhawk, a division of ZAPATA ENGINEERING 301 Commercial Road, Suite B Golden, Colorado 80401	11. Contract or Grant No. DTFH68-03-P-00116

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Federal Highway Administration Central Federal Lands Highway Division 12300 West Dakota Avenue Lakewood, Colorado 80228	Final Report, May 2003-March 2005
	14. Sponsoring Agency Code HFTS-16.4

15. Supplementary Notes

COTR: Khamis Haramy, FHWA-CFLHD. Advisory Panel: Scott Anderson, FHWA-FLH and Roger Surdahl FHWA-CFLHD. This project was funded under the Federal Lands Highway Technology Deployment Initiatives and Partnership Program (TDIPP.)

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:

a) What constitutes a defect in a drilled shaft?; and,
b) How to relate observed defect in a velocity tomogram to engineering strength information?

This study was conducted based on the development of a three-step approach:

1) *Anomaly Identification and Independent Verification* - This step allows the engineer to identify and independently verify suspected **"anomalies"** in drilled shafts. It is concluded that both crosshole sonic logging (CSL) and gamma-gamma density logging (GDL) must be used. For velocity imaging of the shaft's interior, three-dimensional crosshole sonic logging tomography (CSLT) is required.

2) Defect Definition – 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 **"defect"** volume.

3) Defect Characterization – Finally, changes in velocity values in the defect volume is correlated to changes in concrete strength and a 3-D strength image 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.

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.

17. Key Words	18. Distribution Statement
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	No restriction. This document is available to the public from the sponsoring agency at the website http://www.cflhd.gov.

19. Security Classification (of this report)	19. Security Classification (of this page)	20. No. of Pages	21. Price
Unclassified	Unclassified	138	

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
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")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
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
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*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)

ACKNOWLEDGEMENTS

The authors would like to express their sincere appreciation to Mr. Khamis Y. Haramy, COTR of the Federal Highway Administration (FHWA), Central Federal Lands Highway Division (CFLHD) for his guidance, valuable technical assistance, and review during the course of this investigation. The authors would also like to thank Dr. Scott Anderson and Mr. Roger Surdahl of the FHWA-CFLHD for their technical support and review of this report.

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