Pile Driving & Hammer Sizing

(Practice in the state of Indiana)

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Let's talk about…

- Bridge foundations in Indiana
- History of pile driving
  - Pile testing
  - Hammer sizing
- The challenges
- INDOT's approach
  - Pile Driving Analyzer
  - Hammer size memorandum
- Statistics

Bridge foundations in Indiana

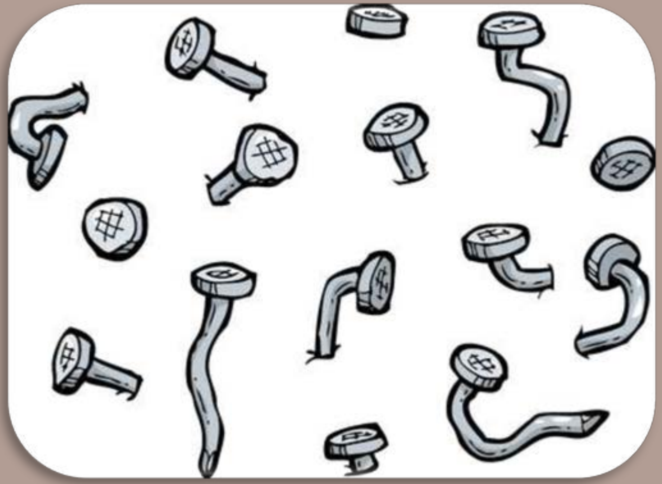
- Types
  - Spread footing
  - Micropiles
  - Drilled shaft
  - Driven Piles
    - Prestresses concrete piles (Not often used)
    - H-piles (HP12x53)
    - Pipe piles (14 in.)
  - Hammers
    - Impact hammers
    - Vibrating hammers

History… Pile testing & Hammer sizing

- Prior to 1990's, no field testing of piles
  - Indiana Department of transportation (INDOT) will relied completely on the engineering news record (ENR) formula for determining pile capacities.
  - ENR formula has factor of safety ranging from 0.5 to 12.
- Hammer sizing
  - First 30T, then 70T, and by 2010, with the use LRFD design load went up as high as 350T per pile.
  - Designers will make an effort to reduce the number of piles. Focus on integral abutments.
  - For hammer sizing, contractor will submit a hammer for INDOT's approval.

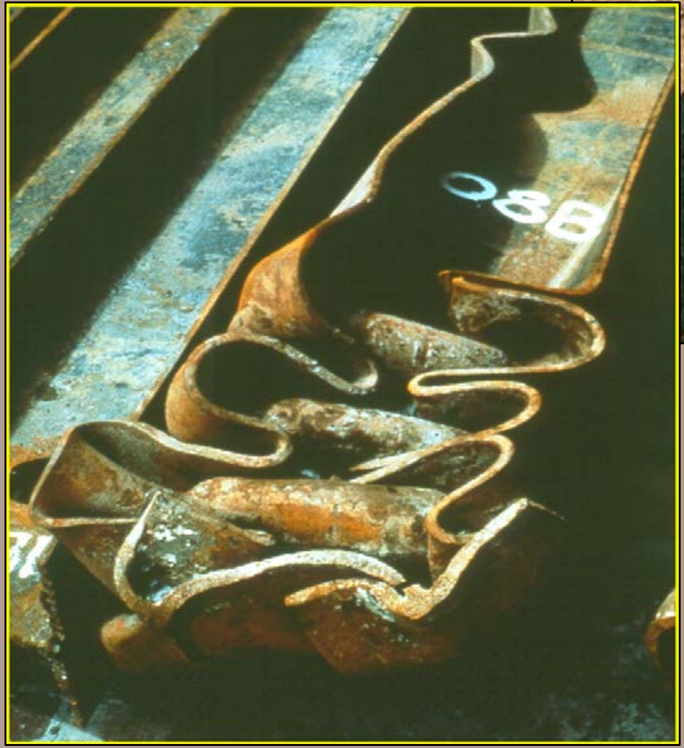
The challenges

- Cost
  - Less piles = increase pile size
  - Increase pile size = higher driving resistance
  - Higher driving resistance = bigger hammer
  - Bigger hammer = bigger crane
  - = Higher cost
- Pile damage or hammer damage
  - Added cost



The challenges

- Problems

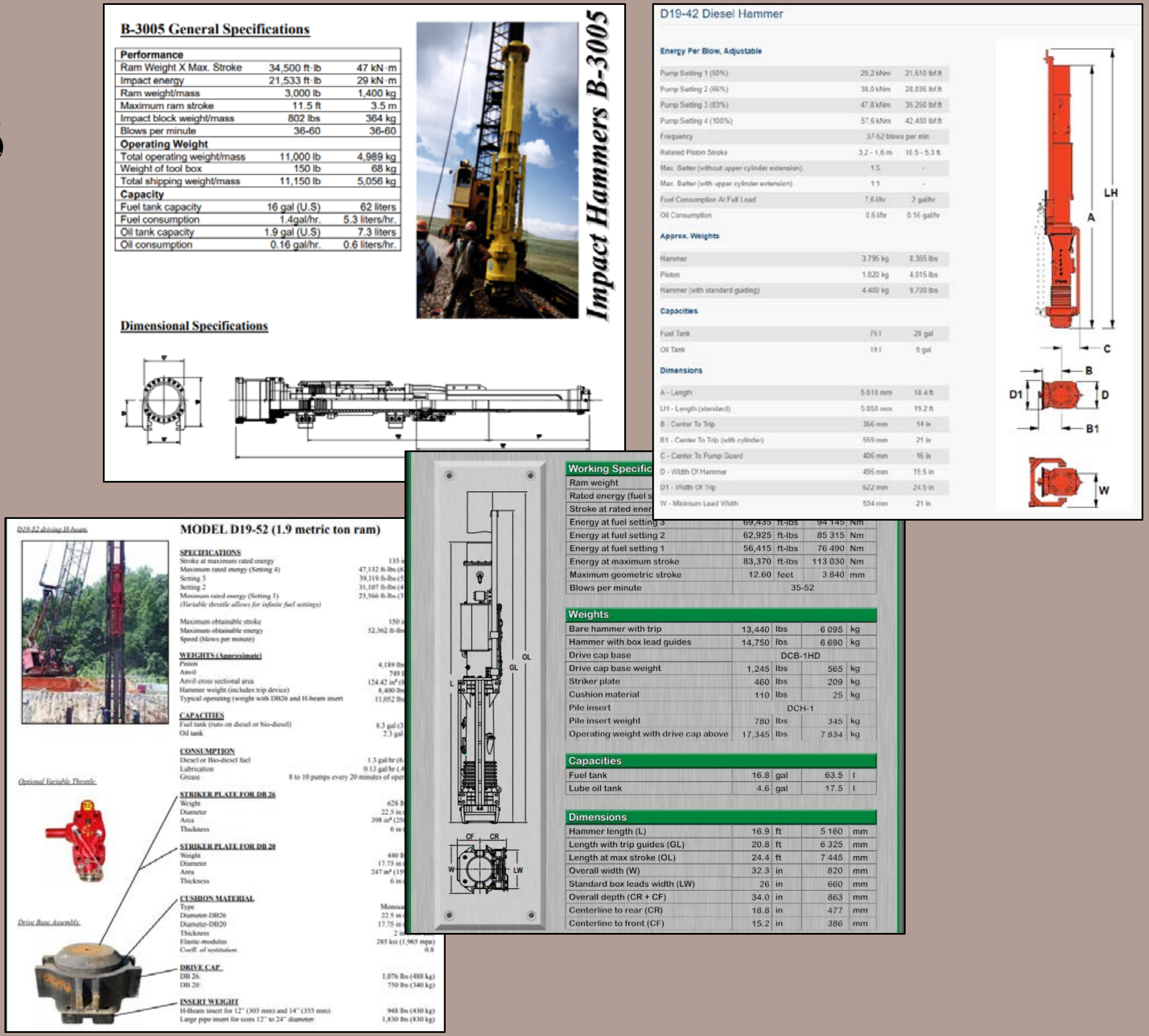


The challenges

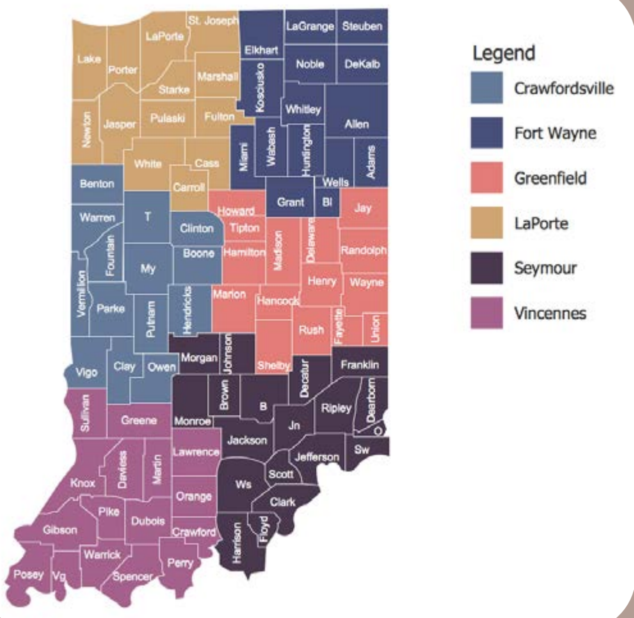
- Problems

The challenges

- Unknown hammer performance
- No validation of the estimated soil conditions
- No monitoring of the pile driving operations
- Change orders during construction due to pile quantities



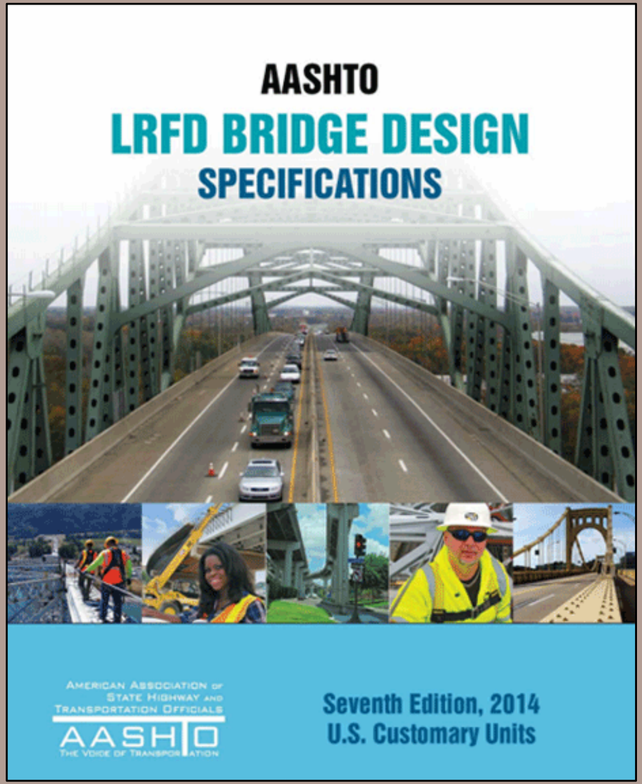
Let’s get to work…



- In 1992, INDOT started looking into testing technologies.
- Conducted workshops and started a research project with 6 pilot projects, one on each districts
- After discussing the results with FHWA a few changes were incorporated into INDOT’s practice
- 1996
  - Gates Formula
    - Safety factor = 2.5
  - Pile Driving Analyzer (PDA)
    - Safety factor = 2.0

Let's get to work…

- In 2010, based on FHWA/AASHTO requirements, INDOT required all foundation designs to follow AASTHO LRFD.
  - Resistance factor is computed in terms of probability of failure (reliability index)
  - Increase the resistance factor to make it more economical
  - With risk of foundation failure, capacity evaluation is necessary.



Less Testing = Higher Risk

Accurate Testing = Lower Risk

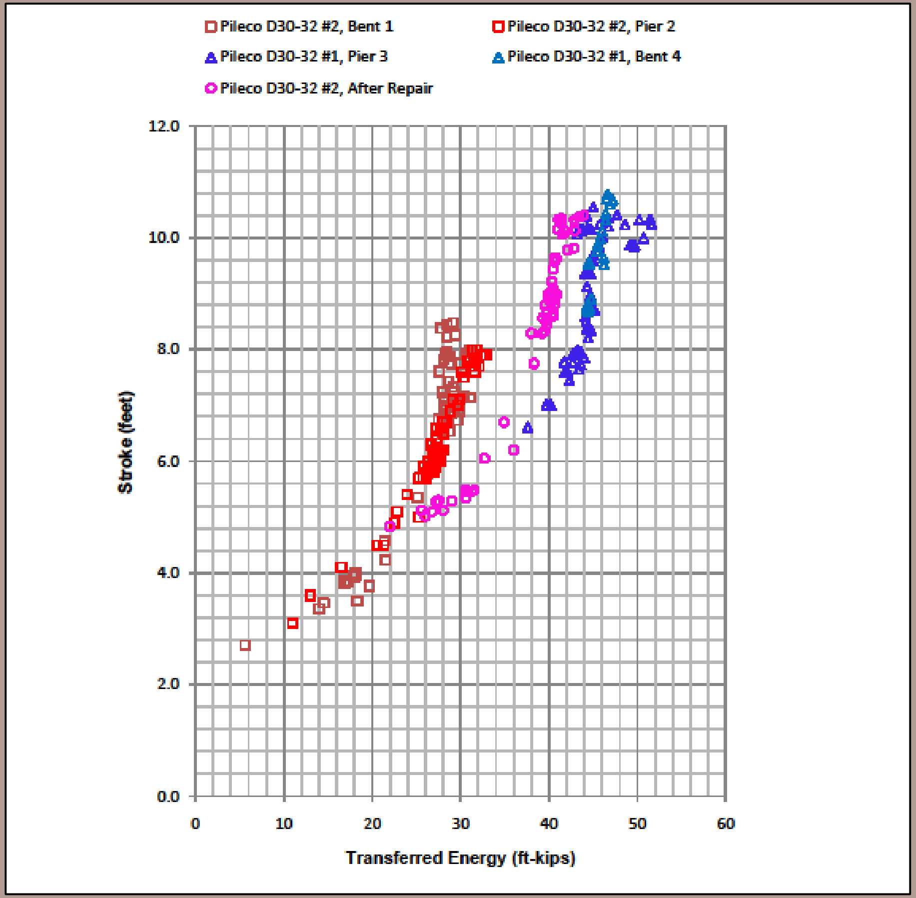
Pile Driving Analyzer (PDA)

- Improve understanding of driven pile design and construction
- Improve understanding of soil condition
- Improve construction practices
- Provide quality assurance



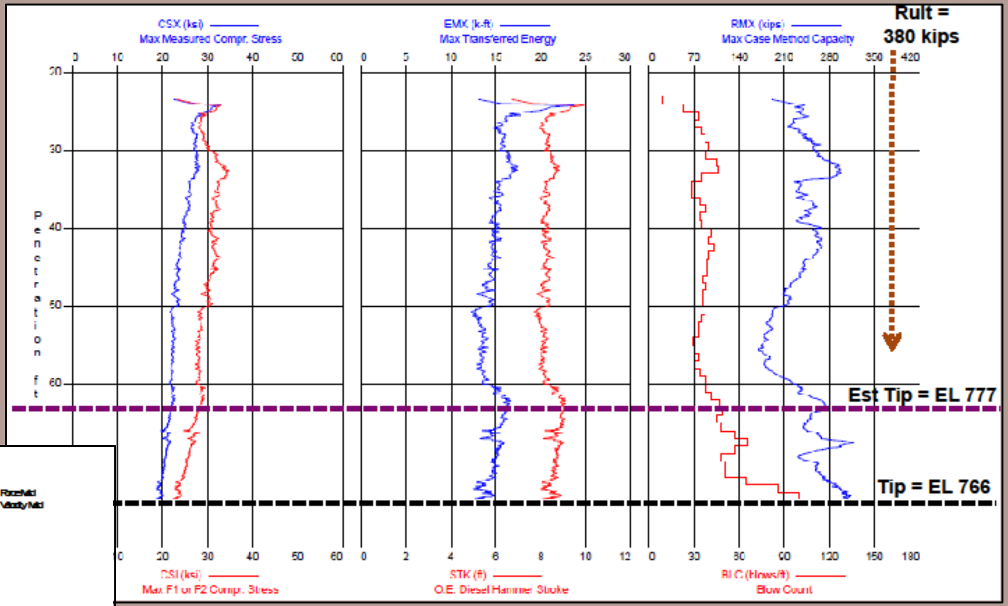
Pile Driving Analyzer (PDA)

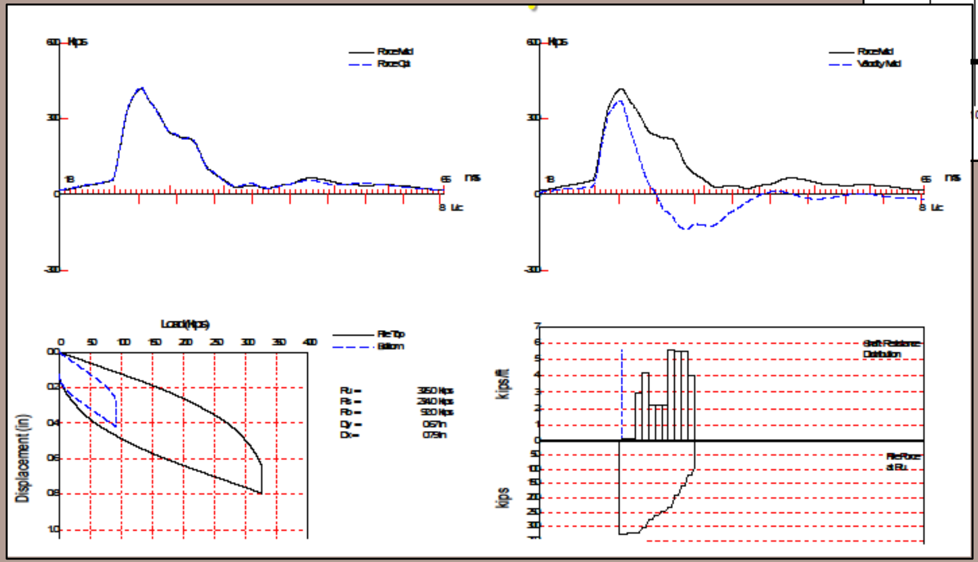
- Hammer performance
  - Same hammer model
  - Different location on the same project
  - Before and after hammer was repaired
- Engineers rely on the blow count as driving criteria for pile acceptance
- Checking the hammer performance assure that initial driving criteria is valid throughout the entire project



Pile Driving Analyzer (PDA)

- Dynamic pile testing with signal matching CAPWAP is used to evaluate pile capacity
- It provides driving stresses; too large can cause pile damage





Pile Driving Analyzer (PDA)

- Knowing the benefits
  - Reliability
  - Confidence (right depth and pile type)
- INDOT's criteria for the use of PDA
  - PDA is not required on every INDOT project because it will not be cost effective
  - Cost of pilling < $100,000, generally no PDA or Static load test is recommended (Unless soil conditions warrant it).
  - $100,000 < Cost of pilling < $500,000, PDA is recommended.
  - Cost of pilling > $500,000, PDA and Static load test is recommended.
- When required, one PDA per bent.
  - If twin bridges are constructed, PDA can staggered between the two bridges.
  - No PDA if driving to bedrock.

Hammer size memorandum

- Pile driving (No. 18-15), published on August 6, 2018
- Cost-effective pile foundation
  - Number of piles
  - Driving equipment
- Change the mentality of “make it bigger to have less piles”

INDIANA DEPARTMENT OF TRANSPORTATION

Driving Indiana’s Economic Growth

Design Memorandum No. 18-15
Technical Advisory

August 6, 2018

TO:	**All Design, Operations, and District Personnel, and Consultants**
FROM:	***/s/Elizabeth W. Phillips*** **Elizabeth W. Phillips** **Manager, Office of Standards and Policy** **Bridge Design Division**
SUBJECT:	**Pile Driving**
REVISES:	***Indiana Design Manual* (IDM) Section 408-3.01**
EFFECTIVE:	**Stage 3 submittals on or after September 1, 2018**

A cost-effective pile foundation should consider both the number of piles driven, as well as the pile driving equipment necessary for installation. Increasing the nominal driving resistance, R_{ndr}, may reduce the total number of piles, but increase the installation costs when a contractor must rent a larger hammer and/or crane to achieve the higher driving resistance.

Designers should limit R_{ndr} to 426 kips for routine bridge projects. This value correlates to commonly owned pile hammers with maximum energy ratings of 69,000-75,000 ft-lbs. Limiting R_{ndr} also reduces the risk of pile damage during installation.

Higher R_{ndr} values may be feasible based on specific site conditions where higher installation costs are offset by a significant reduction in the number of piles. Where higher R_{ndr} values are considered appropriate, the designer should coordinate with the project geotechnical engineer.

The *Indiana Design Manual* has been revised to incorporate this guidance and is included for reference on the following page.

Contact Jeremy Hunter with questions and comments at (317) 233-2096 or by email at jhunter@indot.in.gov.

Hammer size memorandum

- Designers should limit the nominal driving resistance to 426 kips
- Use hammer with a maximum energy rating of 69,000 lbs. – 75,000 lbs.

Pile Type	Section Area, in.^{2}	Maximum Nominal Soil Resistance, $R_{n\,max}$, kip
HP 10x42	12.4	341
HP 10x57	16.8	462
HP 12x53	15.5	426
HP 12x63	18.4	506
HP 12x74	21.8	600
HP 12x84	24.6	677
HP 14x73	21.4	589
HP 14x89	26.1	718
HP 14x102	30.0	825
HP 14x117	34.4	946
Pipe pile, 14 in.	n/a	420
Pipe pile, 16 in.	n/a	480

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Hammer size memorandum

- Benefits
  - Construction crews can use commonly owned pile hammers
  - Cost of mobilization reduced
  - Avoid delays (waiting for availability of a big hammer)
  - Reduce the risk of pile damage during the installation

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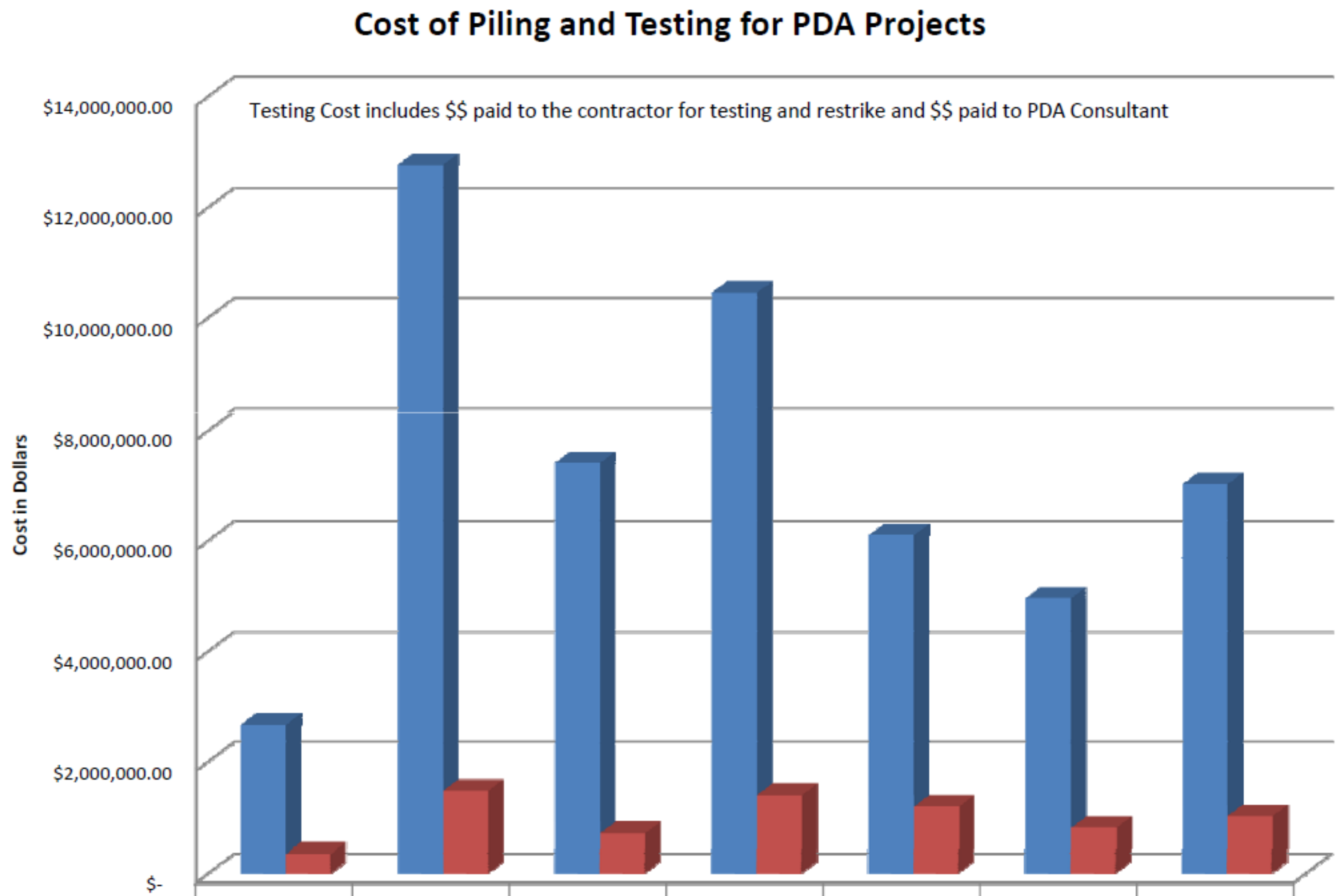
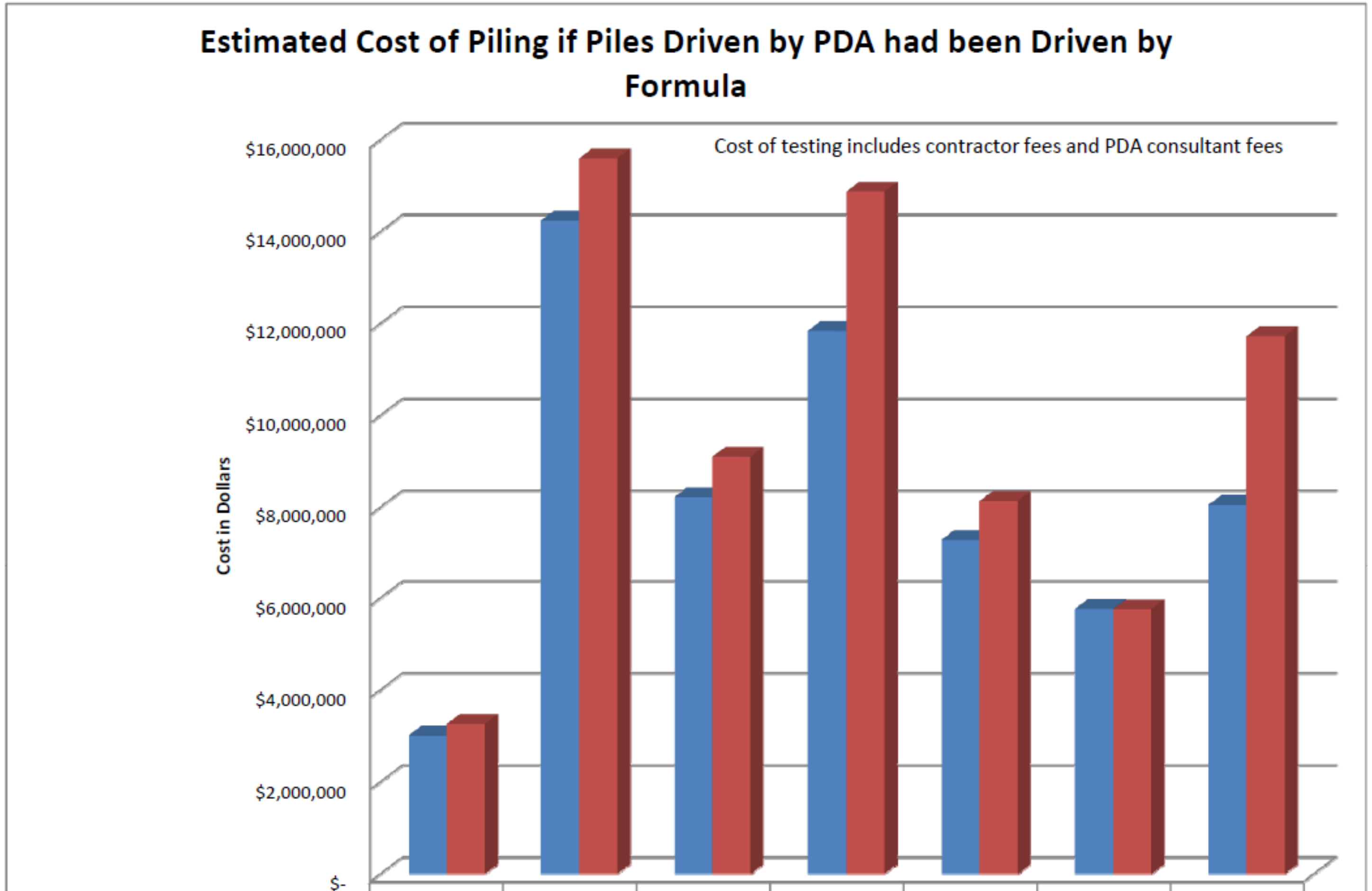
Statistics



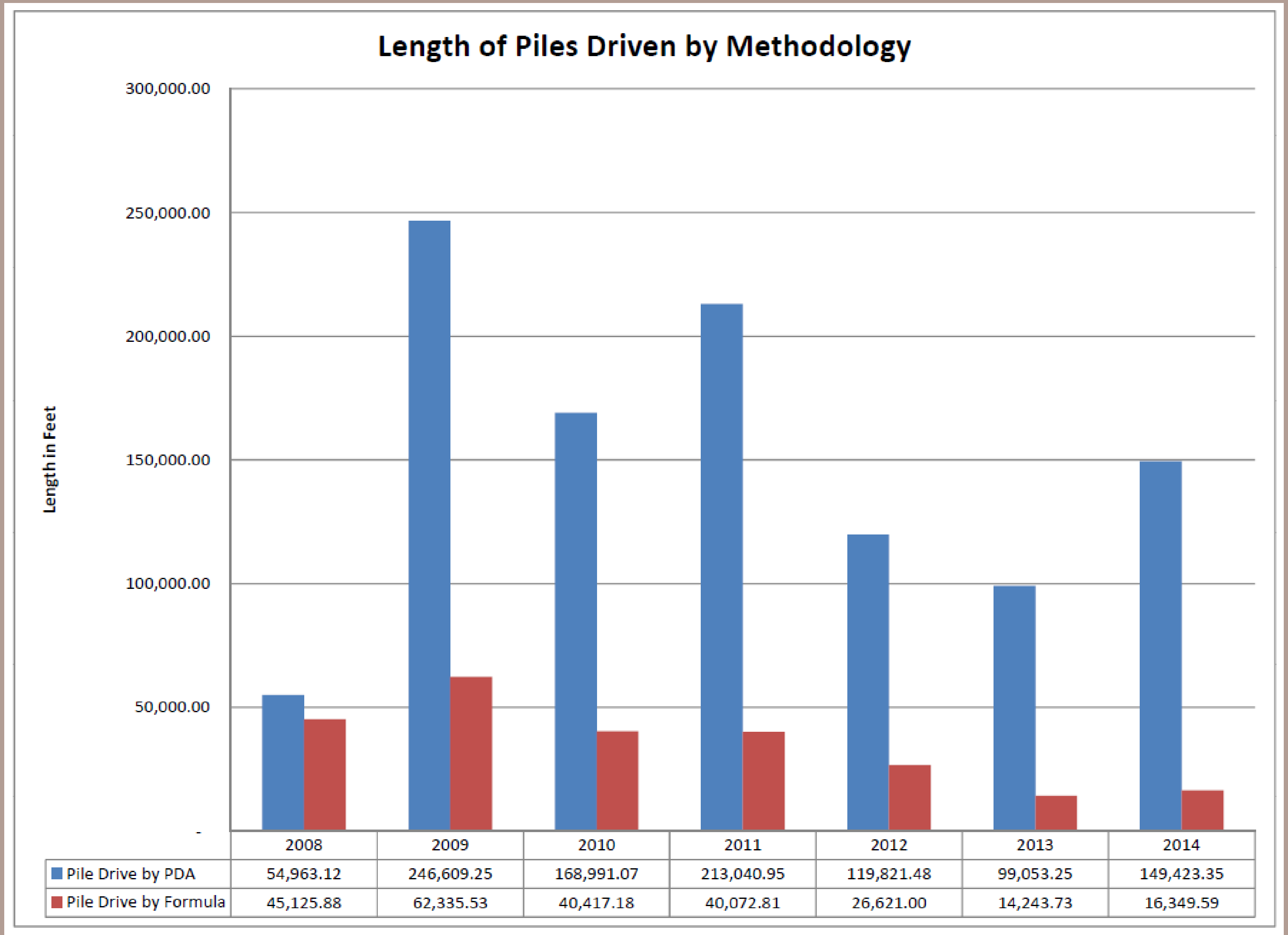
	2008	2009	2010	2011	2012	2013	2014
Cost of Piling	$2,670,157.39	$12,769,307.32	$7,416,701.90	$10,451,318.46	$6,101,235.83	$4,956,839.99	$7,031,528.57
Cost of Testing	$345,902.44	$1,476,682.14	$716,207.74	$1,394,247.27	$1,191,067.87	$809,724.51	$1,021,863.97

Statistics



	2008	2009	2010	2011	2012	2013	2014
Actual Cost of Piling and PDA Testing	$3,016,059.8	$14,245,989.	$8,224,485.3	$11,845,565.	$7,292,303.7	$5,766,564.5	$8,053,392.5
Estimated Cost if Driven by Formula	$3,263,068.0	$15,594,702.	$9,106,732.1	$14,871,302.	$8,140,850.8	$5,757,807.0	$11,730,450.

Statistics



Length of Piles Driven by Methodology
Length in Feet
300,000.00
250,000.00
200,000.00
150,000.00
100,000.00
50,000.00
-
2008
2009
2010
2011
2012
2013
2014
Pile Drive by PDA
54,963.12
246,609.25
168,991.07
213,040.95
119,821.48
99,053.25
149,423.35
Pile Drive by Formula
45,125.88
62,335.53
40,417.18
40,072.81
26,621.00
14,243.73
16,349.59

Statistics

SECTION	ITEM	DESCRIPTION	UNIT	LOW PRICE	HIGH PRICE	WGT AVG	NO ITEMS	TOTAL ($)	PDA Cost % of Piling Cost
2008									
701	701-06011	DYNAMIC PILE LOAD TEST	EACH	775.36	9,000.00	$ 2,899.58	90.00	$ 260, 962.20	1.99
701	701-06012	TEST PILE, RESTRIKE	EACH	825.00	3,933.41	$ 2,013.49	90.00	$ 181, 214.10	1.38
701		TOTAL PILING COST	LFT				254,800	$ 13,142,856.43	
2009									
701	701-06011	DYNAMIC PILE LOAD TEST	EACH	800.00	5,000.00	1,722.97	169.00	$ 291,181.93	2.92
701	701-06012	TEST PILE, RESTRIKE	EACH	800.00	3,332.86	1,380.23	96.00	$ 132,502.08	1.33
701		TOTAL PILING COST	LFT				231,926	$ 9,965,391.35	
2010									
701	701-06011	DYNAMIC PILE LOAD TEST	EACH	0.00	5,900.00	1,527.15	202.00	$ 308,484.30	2.86
701	701-09559	TEST PILE, RESTRIKE	EACH	0.00	2,900.00	970.35	208.00	$ 201,832.80	1.87
701		TOTAL PILING COST	LFT				263,190	$ 10,782,760.20	
2011									
701	701-06011	DYNAMIC PILE LOAD TEST	EACH	$250.00	$3,500.00	$1,552.14	201	$ 311,980.14	3.08
701	701-09559	TEST PILE, RESTRIKE	EACH	$250.00	$3,500.00	$1,138.41	201	$ 228,820.41	2.26
701		TOTAL PILING COST	LFT				208,313	$ 10,141,536.07	
2012									
701	701-06011	DYNAMIC PILE LOAD TEST	EACH	$405.00	$3,512.35	$1,425.05	162.00	$ 230,858.16	2.25
701	701-09559	TEST PILE, DYNAMIC, RESTRIKE	EACH	$500.00	$4,125.00	$1,203.67	158.00	$ 190,179.53	1.85
701		TOTAL PILING COST	LFT				234,367	$ 10,272,846.64	
2013									
701	701-06011	DYNAMIC PILE LOAD TEST	EACH	$1.00	$6,300.00	$1,839.60	131.00	$ 240,988.05	3.24
701	701-09559	TEST PILE, DYNAMIC, RESTRIKE	EACH	$500.00	$4,000.00	$1,317.67	128.00	$ 168,661.84	2.27
701		TOTAL PILING COST	LFT				160,758	$ 7,435,914.50	

Contacts

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Thank you!