

Automated Pile Driving Data Acquisition Devices

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Derek Fuller

108th Annual Purdue Road School

March 16th 2022

Outline

- INDOT Driven Pile Practices
- Currently Available Approved Devices
 - SmartPile Inspector by Smart Structures
 - E-Saximeter or SAX-Q by PDI
- Automated Pile Driving Data collection projects
- E-Construction – Current Work at INDOT
- Data Management
- Future Plans

INDOT Driven Pile Practices

701.08 Requirements:

When the nominal driving resistance is determined in accordance with 701.05(a), for acceptance, the Engineer will record, at a minimum, the number of hammer blows per inch or per foot of pile movement for the last 24 in. of driving.

When the nominal driving resistance is determined in accordance with 701.05(b), for acceptance, the Engineer will record the blow count per inch or foot of pile movement and the associated hammer stroke for the last two consecutive feet of driving, and the final pile tip elevation as per the pile driving criteria established through the dynamic pile load test.

INDOT Driven Pile Practices

- Current Pile Driving Records IC-225

Weather: cloudy Temperature: 65 °F Start Time: 6:45pm Stop Time: 7:45pm

Feet	Blows	Stroke/Pressure	Comments	Feet	Blows	Stroke/Pressure	Comments
0.0 - 1.0				35.0 - 36.0			
1.0 - 2.0				36.0 - 37.0			
2.0 - 3.0				37.0 - 38.0			
3.0 - 4.0				38.0 - 39.0			
4.0 - 5.0				39.0 - 40.0			
5.0 - 6.0				40.0 - 41.0			
6.0 - 7.0				41.0 - 42.0			
7.0 - 8.0				42.0 - 43.0	57	8	
8.0 - 9.0				43.0 - 44.0	50	8	
9.0 - 10.0				44.0 - 45.0	56	8.5	
10.0 - 11.0				45.0 - 46.0	64	9	
11.0 - 12.0				46.0 - 47.0	70	9	
12.0 - 13.0				47.0 - 48.0			
13.0 - 14.0				48.0 - 49.0			
14.0 - 15.0				49.0 - 50.0			
15.0 - 16.0				50.0 - 51.0			
16.0 - 17.0							
17.0 - 18.0							
18.0 - 19.0							
19.0 - 20.0							
20.0 - 21.0							
21.0 - 22.0							
22.0 - 23.0							
23.0 - 24.0							
24.0 - 25.0							
25.0 - 26.0							
26.0 - 27.0							
27.0 - 28.0							
28.0 - 29.0							
29.0 - 30.0							
30.0 - 31.0							
31.0 - 32.0							
32.0 - 33.0				67.0 - 68.0			
33.0 - 34.0				68.0 - 69.0			
34.0 - 35.0				69.0 - 70.0			

39.0 - 40.0			
40.0 - 41.0			
41.0 - 42.0			
42.0 - 43.0	57	8	
43.0 - 44.0	50	8	
44.0 - 45.0	56	8.5	
45.0 - 46.0	64	9	
46.0 - 47.0	70	9	
47.0 - 48.0			
48.0 - 49.0			
49.0 - 50.0			

STATE HIGHWAY DEPARTMENT OF INDIANA
 CONTRACT NO. B-5440 DATE June 11, 1962
 STATE DES. I-74-170-1484/J RECORD NO. 4a
 FED. DES. I-74-4(61)170 PILE DRIVING RECORD FOR 12" Steel H
 TYPE OF PILE Cast Steel Girder TYPE OF HEAD Downey D-12
 TYPE NUMBER 35' ORDINARY

Pile # 4 (cont.)

Pile and Pile Number	Depth, Feet to Lead	Length, Feet to Last Blow	Length, Feet to 20 Blows	Blows per Foot	Weight and Drive of PPM and Energy	Bearing Value in Tons	Remarks
4-40	35	12	358	34	2750 6.4'	56.5	June 11, 1962
4-37	35	12	358	34		62.5	
4-38	35	13	357	35.2		62.5	SOUTH PAD
4-39	35	2.7	32.8	12.1		70.4	45' MAX
4-36	35	12	358	34		62.5	
4-33	35	13	357	35.2		62.5	
4-32	35	13	357	35.2		56.3	
4-35	35	0.8	34.2	42.5		56.3	June 13, 1962
4-31	35	10	340	34.0		56.3	
4-27	35	2.0	33.0	16.5		66.3	
4-28	35	1.8	33.7	19.2		66.3	
4-22	35	1.3	33.7	26.3		62.5	SOUTH PAD
4-26	35	2.0	33.0	16.5		62.5	
4-30	35	2.5	32.5	12.0		62.5	
4-34	35	1.3	33.7	26.3		62.5	
4-21	35	0.7	34.3	49.3		52.3	
4-25	35	1.0	34.0	34.0		56.3	
4-29	35	1.1	33.9	30.8		62.5	
4-33	35	5.0	30.0	7.0		70.4	
4-41	35	3.0	32.0	11.7		70.4	June 13, '62 - Nov 10
4-2	35	1.3	33.7	26.3		62.5	
4-1	35	1.3	33.7	26.3		56.3	June 13, 1962
4-5	35	1.5	32.5	21.7		56.3	
4-3	35	2.2	32.8	14.9		70.4	
4-13	35	2.2	32.8	14.9		56.3	
4-8	35	1.2	33.8	28.2		56.3	
4-19	35	2.3	32.7	14.3		62.5	
4-14	35	1.0	34.0	34.0		62.5	June 14, 1962
4-8	35	1.0	34.0	34.0		56.3	
4-10	35	1.0	34.0	34.0		56.3	
4-11	35	1.0	34.0	34.0		56.3	
4-12	35	1.0	34.0	34.0		56.3	
4-14	35	1.8	34.0	18.9		70.4	
4-15	35	1.8	34.0	18.9		62.5	
4-16	35	3.0	32.0	10.7		66.3	
4-20	35	1.0	34.0	34.0		70.4	
						56.3	

TOTALS THIS REPORT: 1390.0 604 1226
 TOTALS LAST REPORT: 2123.5 1159 1944.6
 TOTALS TO DATE: 3513.5 1763 3211.2

NOTE: On the back of this sheet make a record of each foundation completed or measured and showing the points of the anchor and the direction of blow of streamer.

NON-ALLOWABLE SPICER
 J. J. Talkum
 P.E.

INDOT Driven Pile Practices

1995 INDOT Standard Specifications: 701.04 (d)

$$P = 2E/(S+1.0) \text{ (For Diesel Hammers)}$$

Use of the above ENR formula ended effective March 14, 1996.

The following were introduced in March of 1996:

- The current dynamic formula (ISS 2022) - FHWA Gates Formula 701.05 (a)

$$R_{ndr} = 1.75 \sqrt{E} \times (\log 10N) - 100$$

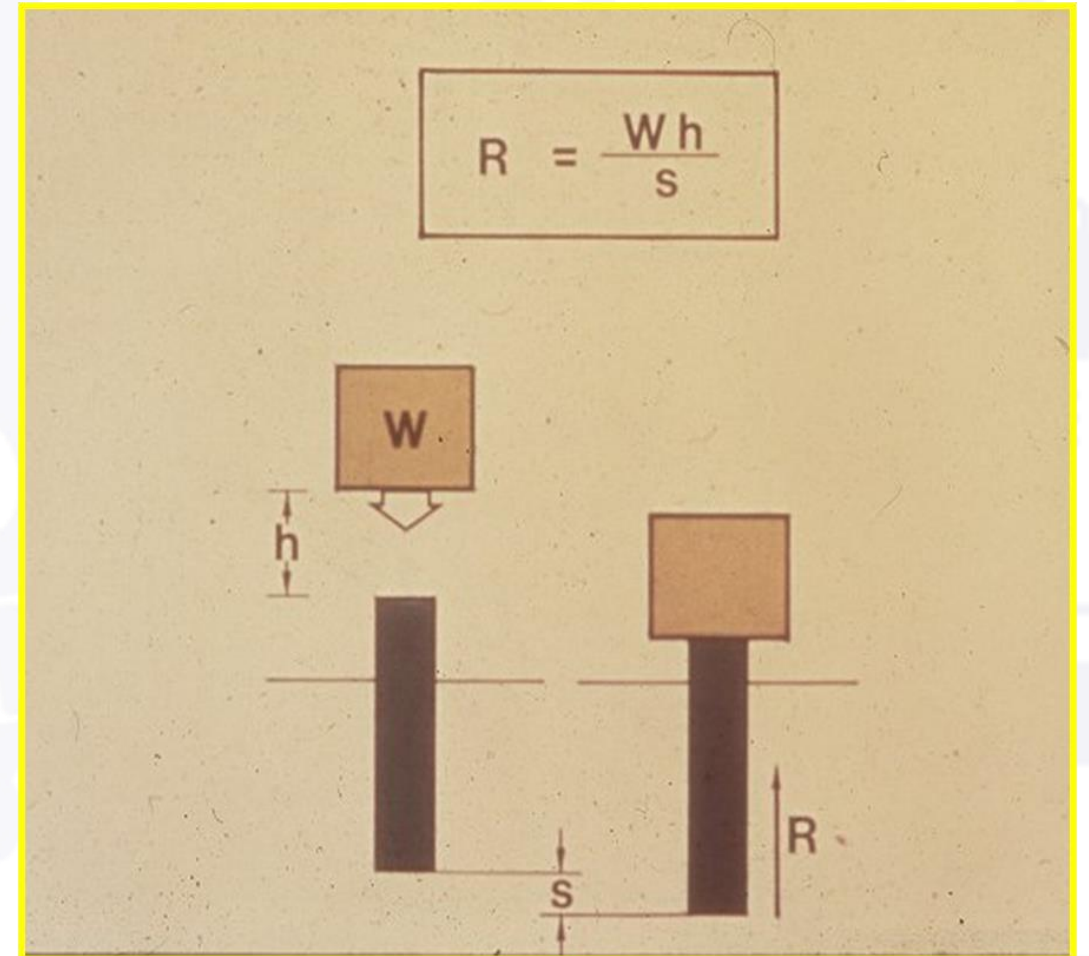
- Dynamic Pile Load Test, PDA, 701.05 (b) and
 - Static Load Test 701.05 (c).

INDOT Driven Pile Practices

Dynamic Formula 701.05(a):

What is not considered?

- Pile Properties
 - Material
 - Dimension
 - Length
- Soil Properties
 - Soil Type
 - Strength
- Hammer Efficiency

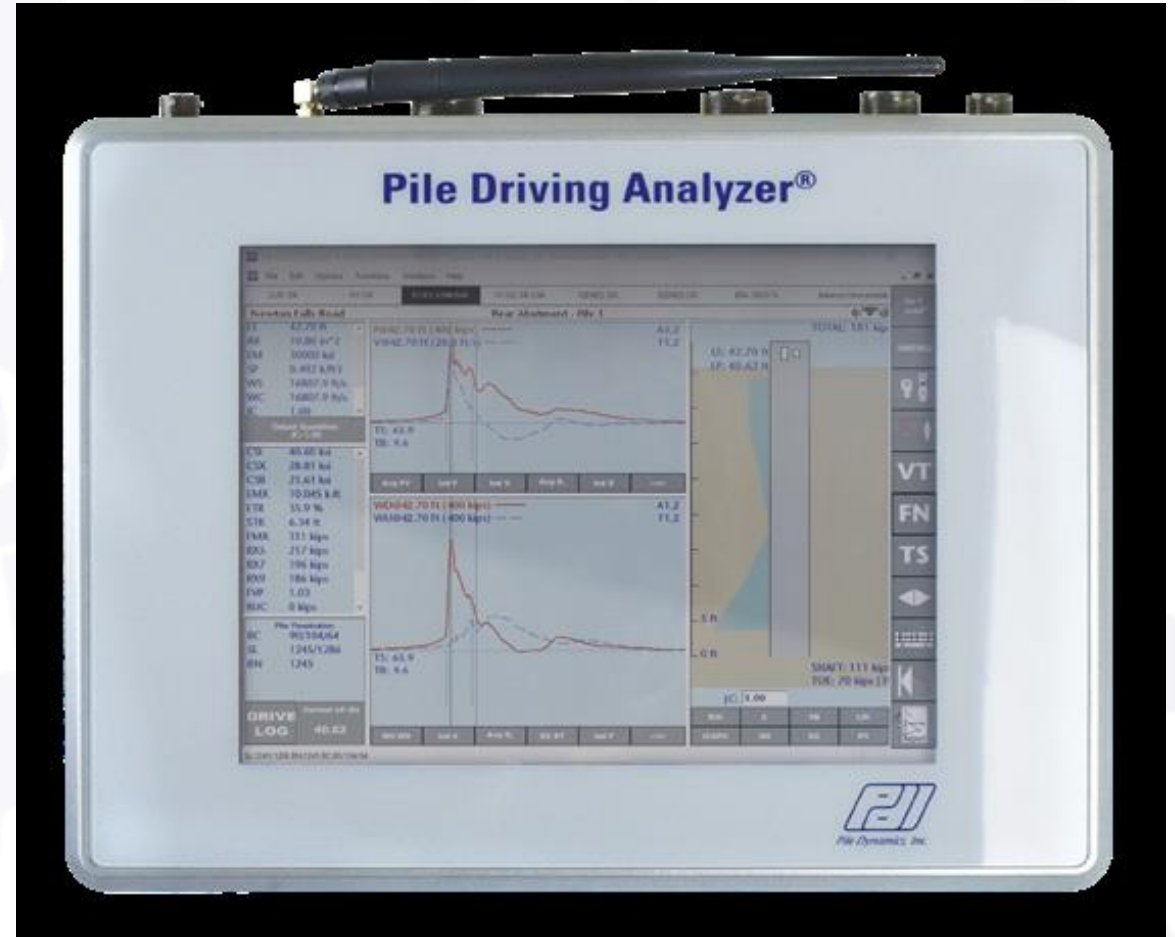


INDOT Driven Pile Practices

- Dynamic Load Test 701.05(b):

What is considered?

- Pile Properties
- Soil Properties
- Hammer Efficiency
- Driving stresses, hammer performance, bearing resistance & Structural Integrity are assessed.



INDOT Driven Pile Practices

- Static Load Test 701.05(c):

This test is always done in conjunction with dynamic pile load test 701.05 (b).



INDOT Driven Pile Practices

LRFD Resistance Factors (AASHTO):

- ENR Formula – 0.10 : INDOT does not use this.
- Gates Formula – 0.40 (0.55 - INDOT)
- WEAP (no PDA) – 0.50 : INDOT does not use this.
- PDA (2% of piles) – 0.65 (0.70 - INDOT)
- PDA (100% of piles) – 0.75
- SLT (1 pile) – 0.75
- SLT (1) and PDA (2%) – 0.80

E-Construction

As stated in the March 18, 2021 edition of EDC News Weekly Newsletter:

- "Using electronic or digital processes simplifies handling and integration of pile driving data into construction management or document management systems for acceptance, payment, and source documentation helps States reap the benefits of the efficiency and transparency of e-Construction."

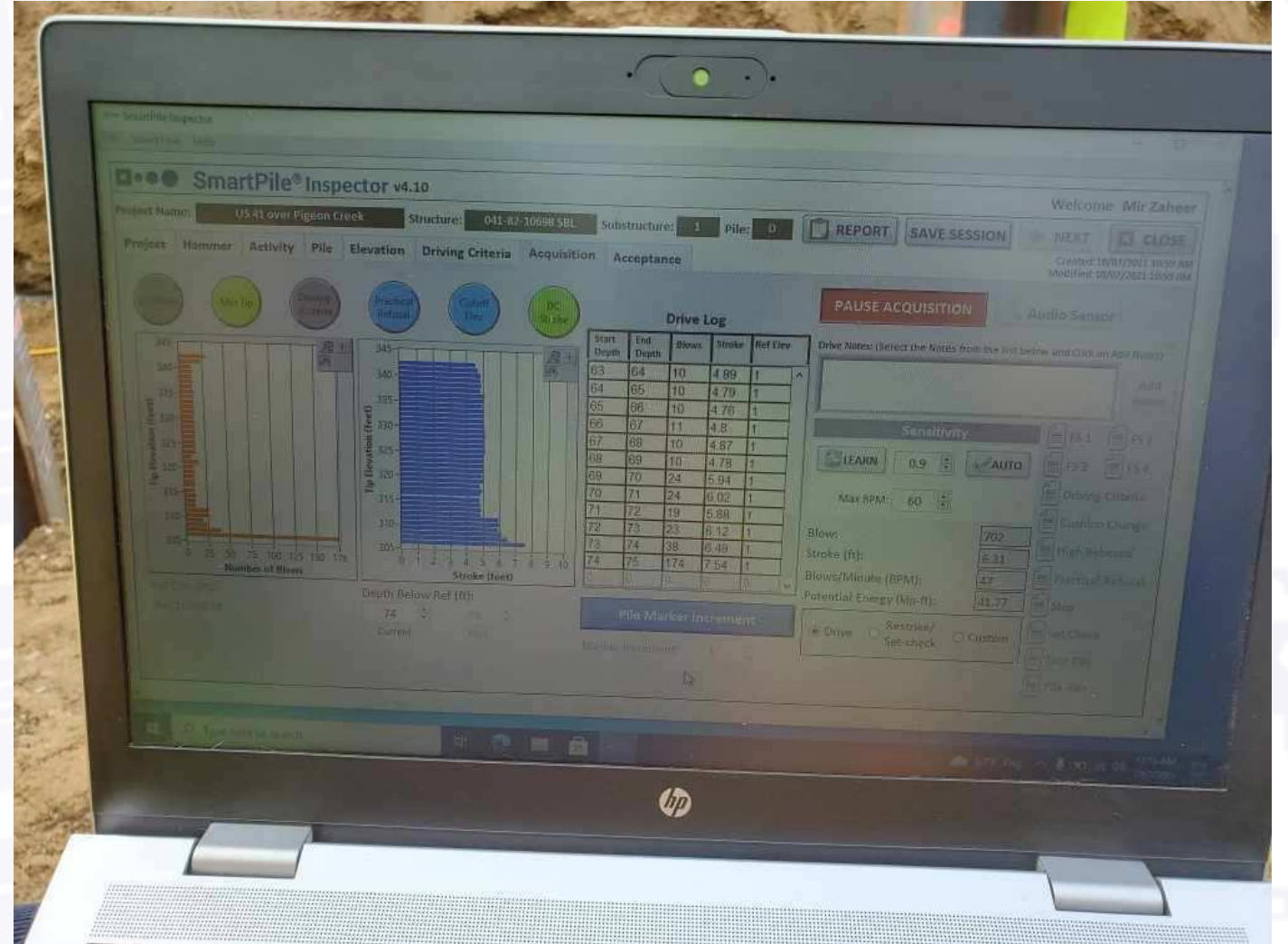
Smart Pile Inspector



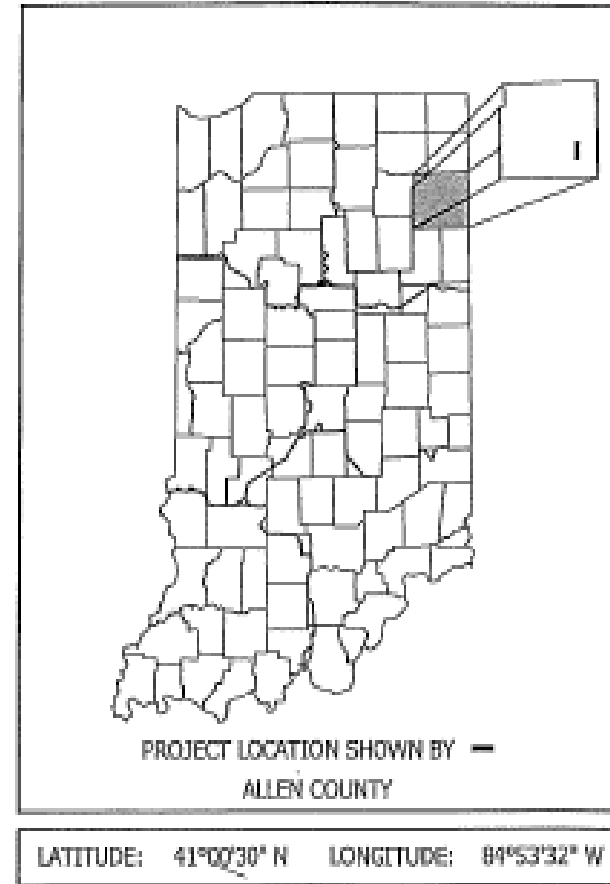
E-Saximeter – SAX- Q



Automated Pile Driving Data Acquisition Devices

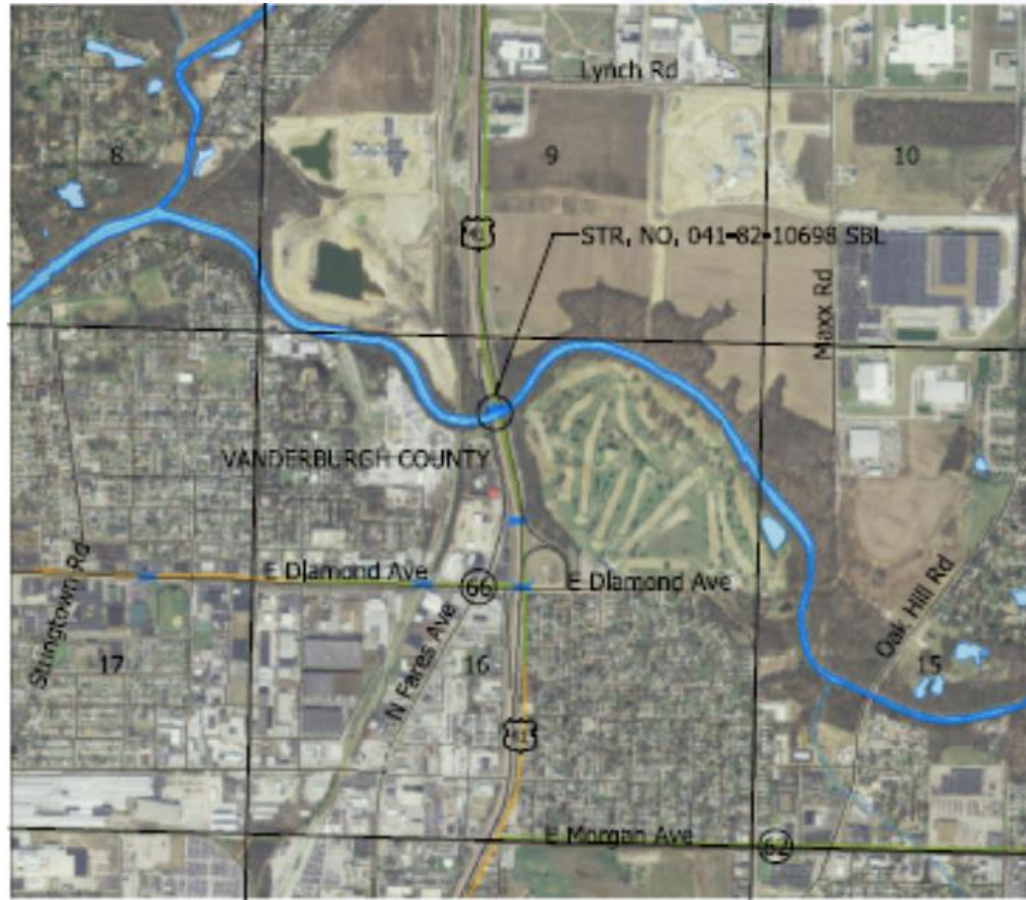


Use of Smart Pile Inspector – Fort Wayne District

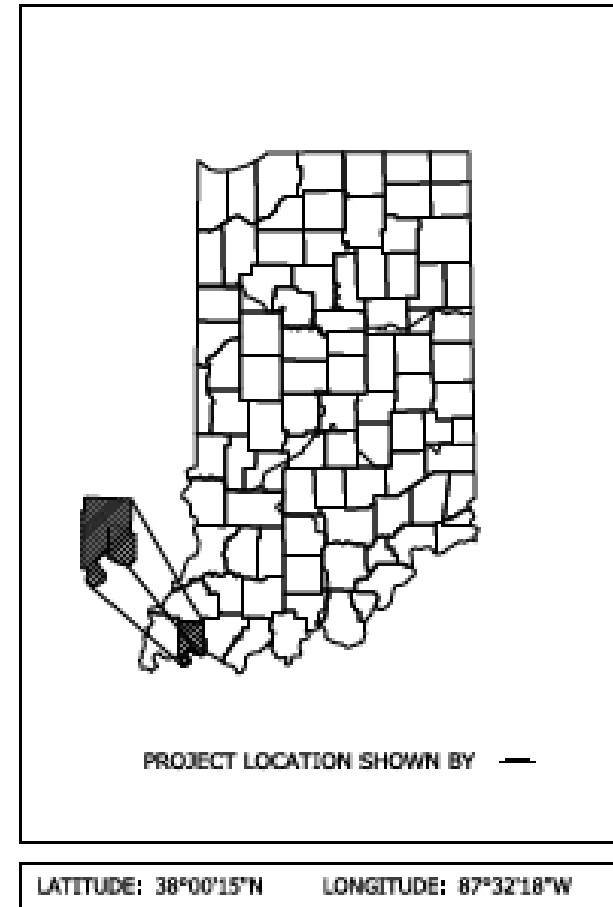


**ALLEN COUNTY BRIDGE NO. 298
TERNET ROAD OVER ELLISON DITCH**

Use of Smart Pile inspector – Vincennes District



LOCATION MAP



BRIDGE PLANS

ROUTE: US 41 SB

Data Collection - Pile Driving Record – Form IC 225

IC 225 (04/09)



INDIANA DEPARTMENT OF TRANSPORTATION
PILE DRIVING RECORD

Contract No.: 38571

Date: 10/07/2021 Bent/Pier No. 1 Test Pile: No

Job Loc./Br. File No.: US 41 over Pigeon Creek

Pile No.: c Pile Type: 14" H Length: 85.00 Helmet Weight: Kips

Hammer: APE D90-42 Rated Energy: 74.42 Operating Rate: 60

Hammer Cushion Type: 2.5" Alum, Blue Nylon t= in Pipe Pile Thickness: 0.0

Pile Tip Attachments: Pile Heat No.:

Nominal Driving Resistance: Kip Resistance Factor: Design Load: Kip

Weather: Temperature: °F Start Time: 11:28 AM Stop Time: 11:38 AM

Feet	Blows	Stroke/Pressure	Comments	Feet	Blows	Stroke/Pressure	Comments
33.00 - 34.00	5	3.91		72.00 - 72.08	16	5.93	
38.00 - 39.00	32	4.31		72.17 - 72.25	1	6.40	
39.00 - 40.00	8	4.54		72.25 - 72.33	1	6.51	
40.00 - 41.00	10	4.48		72.42 - 72.50	1	6.46	
41.00 - 42.00	17	4.64		72.58 - 72.66	1	6.31	
42.00 - 43.00	12	4.65		72.75 - 72.83	1	6.40	
43.00 - 44.00	10	4.65		72.83 - 72.91	1	6.32	
44.00 - 45.00	10	4.61		72.91 - 73.00	1	6.20	
45.00 - 46.00	10	4.80		73.00 - 73.08	2	6.09	
46.00 - 47.00	10	4.82		73.08 - 73.16	2	6.29	
47.00 - 48.00	6	4.81		73.16 - 73.25	2	6.29	
48.00 - 49.00	5	4.63		73.25 - 73.33	2	6.44	
49.00 - 50.00	10	4.80		73.41 - 73.49	1	6.56	
50.00 - 51.00	11	4.76		73.49 - 73.58	3	6.45	
51.00 - 52.00	11	4.81		73.66 - 73.74	1	6.68	
52.00 - 53.00	11	4.96		73.74 - 73.83	2	6.58	
53.00 - 54.00	11	5.06		73.83 - 73.91	2	6.55	
54.00 - 55.00	12	4.94		73.91 - 73.99	11	6.62	
55.00 - 56.00	11	4.87		73.99 - 74.08	4	6.94	
56.00 - 57.00	11	4.83		74.08 - 74.16	5	6.96	
57.00 - 58.00	10	4.90		74.16 - 74.24	4	6.91	
58.00 - 59.00	10	4.78		74.24 - 74.32	6	7.13	
59.00 - 60.00	9	4.74		74.32 - 74.41	6	7.23	
60.00 - 61.00	9	4.74		74.41 - 74.49	14	7.50	
61.00 - 62.00	9	4.61		74.49 - 74.57	15	7.77	
62.00 - 63.00	8	4.57		74.57 - 74.66	41	8.10	
63.00 - 64.00	8	4.54		74.66 - 74.74	3	7.88	
64.00 - 65.00	9	4.42					
65.00 - 66.00	8	4.46					
66.00 - 67.00	8	4.52					
67.00 - 68.00	7	4.42					
68.00 - 69.00	5	4.47					
69.00 - 70.00	22	5.81					
70.00 - 71.00	23	6.08					
71.00 - 72.00	15	5.76					

Min. Tip Elev.: +345.35 Final Tip Elev.: +305.61 Pile Cutoff Elev.: +382.35

Final Pile Alignment: Final Pile Plumbness: Yes Internal Inspection:

Printed Name: Mir Zaheer Title:

Signature: Date: 01/04/2022

IC 225 (04/09)



INDIANA DEPARTMENT OF TRANSPORTATION
PILE DRIVING RECORD

Page 2

Standard Notes and User Defined Notes 1 through 20

Contract No.: 38135

Date: 10/07/2021 Bent/Pier No. 1 Test Pile: No

Project: US 41 over Pigeon Creek

Standard Notes:

- I = Pile Ran
- F1, F2, F3, F4 = (Fuel Settings 1-4)
- ST = Stop
- CC = Cushion Change
- HR = High Rebound
- TP = Test Pile
- DC = Driving Criteria
- PR = Practical Refusal
- SC = Set Check
- DLT = Dynamic Load Test

User Defined Notes 1 through 20:

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.
- 8.
- 9.
- 10.
- 11.
- 12.
- 13.
- 14.
- 15.
- 16.
- 17.
- 18.
- 19.
- 20.

Pile Driving Record – Form IC 225

IC 225 (04/09)



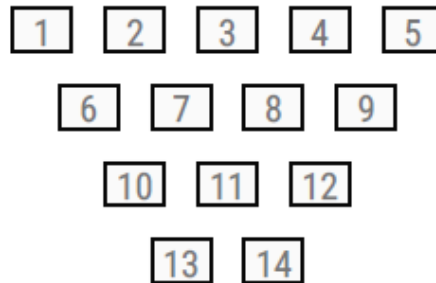
INDIANA DEPARTMENT OF TRANSPORTATION PILE DRIVING RECORD

Page 3

Pile Footing Sketch

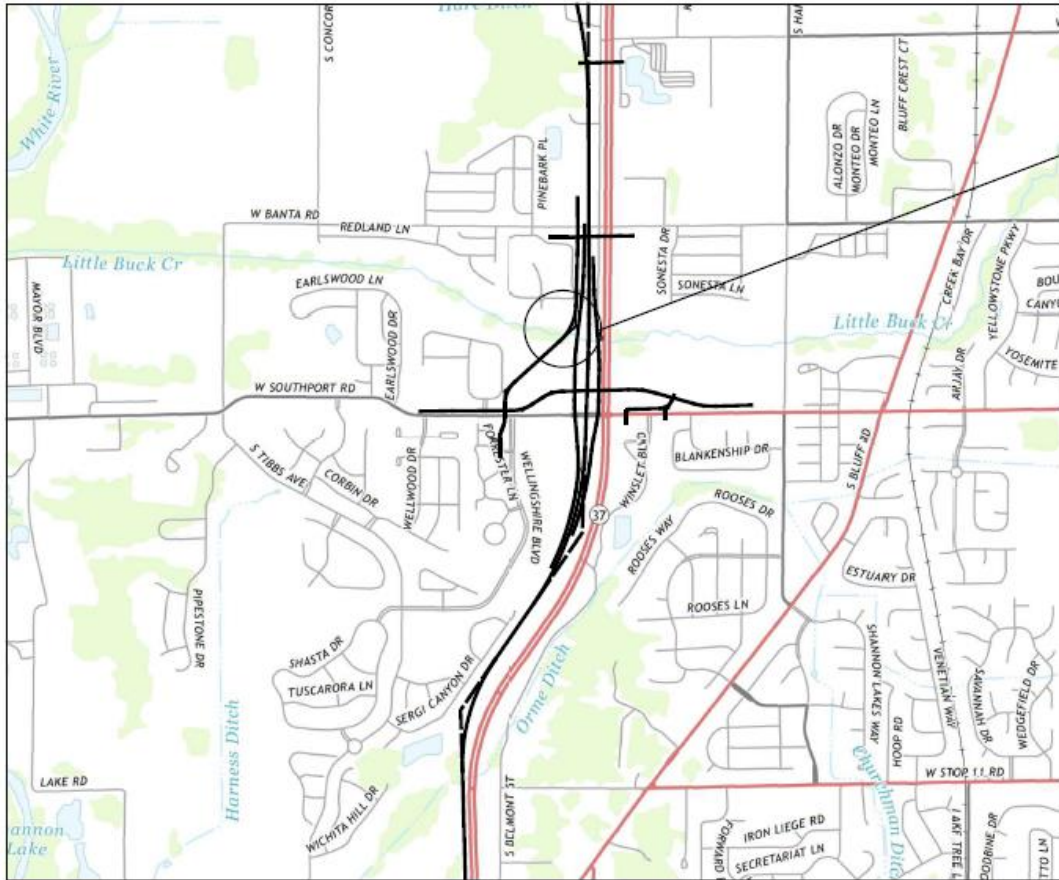
Contract No.: 38135 Project Number: 2000514 Bent/Pier No. 1 Pile Number: c

Pile Footing Sketch:



General Remarks:

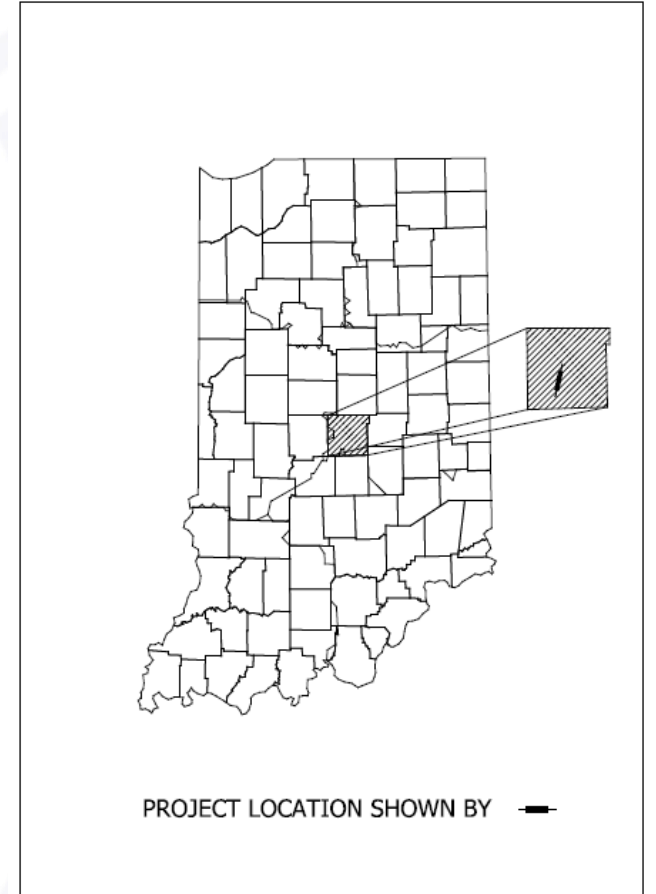
Use of Esaximeter SAX-Q – Greenfield District



STRUCTURE 49-4506-L
S. BELMONT AVE. OVER LITTLE BUCK CREEK
STA. 24+61.51 LINE "SOUTHPORT CONNECTOR-C"



1" = 2000'



LATITUDE: 39°40'00" N LONGITUDE: 86°11'49" W

BRIDGE PLANS

ROUTE: S. BELMONT AVE.

Data Collection - Pile Driving Record – Form IC 225

INDIANA DEPARTMENT OF TRANSPORTATION
PILE DRIVING RECORD

Page 1



Date: 12/13/2021 Bent/Pier No. Bent 1 Contract No.: R-41536
 Test Pile: Pile 1
 Job Loc./Br. File No.: _____

Pile No.: 1 Pile Type: 14"x0.375" CEP Length: 70.25 Helmet Weight: 3.15 kips
 Hammer: D 30-32 Rated Energy: 75.44 Operating Rate: _____ Fuel Setting - 2
 Hammer Cushion Type: Aluminum t= 1.000 in Pile Cushion Type: Micarta t= 1.000 in
 Pile Supplier: _____ Pile Heat No.: _____
 Pile Tip Attachments: Conical Tips Pile Cast or Rolling Date: _____
 Nominal Driving Resistance: 380 kip Resistance Factor: 0.7 Design Load: 255 kip
 Weather: Sunny Temperature: 51.00 °F Start Time: 12:00:00 PM Stop Time: 12:20 PM

Feet	Blows	Stroke/ Pressure	Comments	Feet	Blows	Stroke/ Pressure	Comments
0 - 8	2	0.000		38 - 39	26	7.389	
8 - 9	3	8.704	ing paused, Restarted rec	39 - 40	25	7.270	
9 - 10	10	0.000		40 - 41	23	7.657	
10 - 11	7	5.054		41 - 42	33	7.750	
11 - 12	5	6.273		42 - 43	50	8.208	
12 - 13	5	7.249	ed recording, Recording p	43 - 44	58	8.051	
13 - 20	62	6.422	ing paused, Restarted rec	-	-	-	
20 - 21	8	5.387		-	-	-	
21 - 22	11	7.339		-	-	-	
22 - 23	12	7.039		-	-	-	
23 - 24	12	7.050		-	-	-	
24 - 25	12	7.146		-	-	-	
25 - 26	14	7.301		-	-	-	
26 - 27	17	7.223		-	-	-	
27 - 28	12	7.367		-	-	-	
28 - 29	16	7.377		-	-	-	
29 - 30	12	7.325		-	-	-	
30 - 31	21	7.220		-	-	-	
31 - 32	19	6.730	ing paused, Restarted rec	-	-	-	
32 - 33	0	0.000	Recording paused	-	-	-	
33 - 35	26	6.248	Restarted recording	-	-	-	
35 - 36	3	6.226		-	-	-	
36 - 37	14	6.687		-	-	-	
37 - 38	21	7.598		-	-	-	

Min. Tip Elev.: EL 645.0 Final Tip Elev.: EL 633.95 Pile Cutoff Elev.: _____

Final Pile Alignment: _____ Final Pile Plumbness: _____ Internal Inspection: _____

Has a plan-view sketch of the footing and piling location been completed on the back of this form? _____

Printed Name: Rahul Yadav Title: Staff Engineer - GRL Engineers

Signature: Rahul Yadav

Date: 12/13/2021

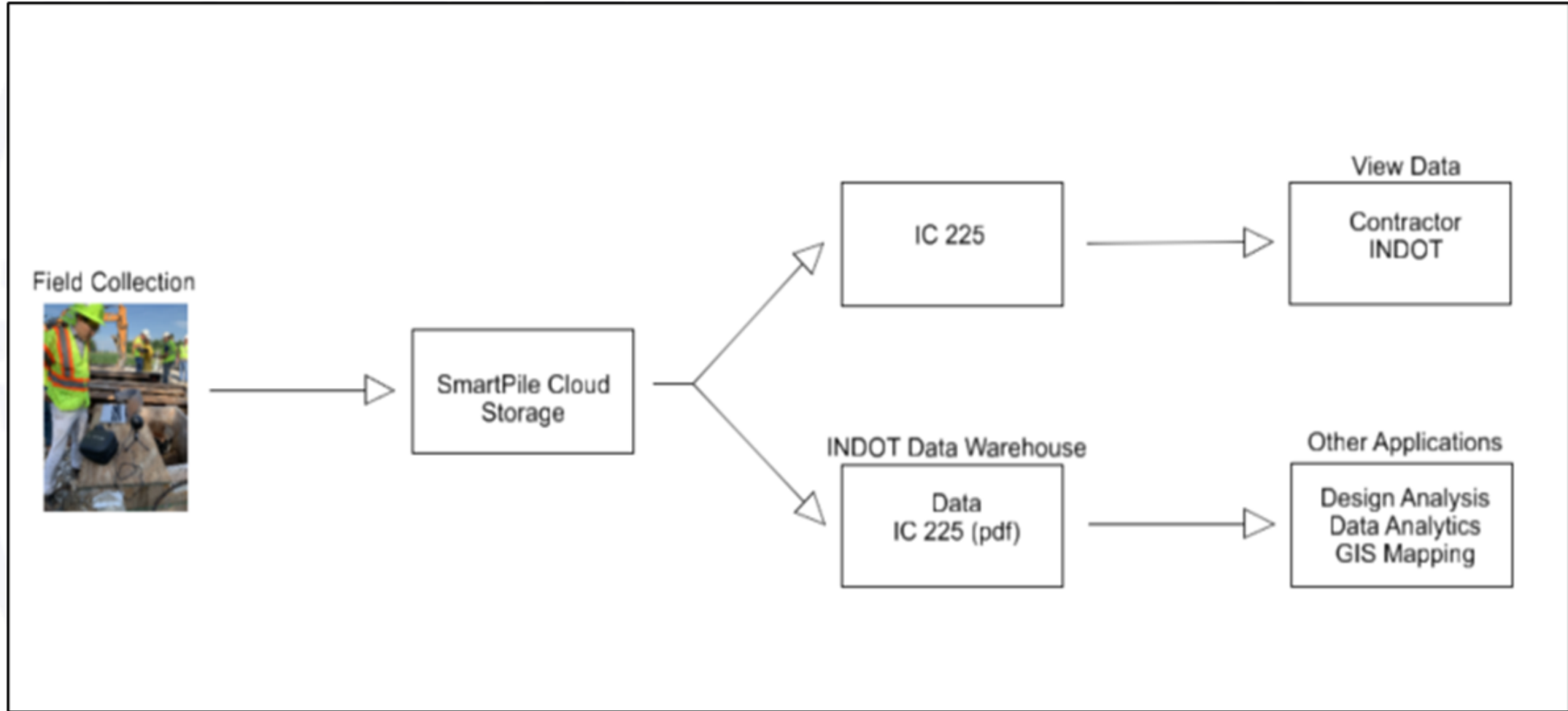
E-Construction

- e-Ticketing for materials delivery
 - Working with vendor HaulHub to pilot/test
 - Digital dashboard displays electronic delivery tickets
 - Eliminates need for paper tickets
 - Automated daily calculations, etc.
- AASHTOWare Project (AWP) Construction and Materials
 - Currently use AASHTO SiteManager
 - AWP is web-based replacement for SiteManager
 - Currently gathering requirements for implementation
 - Anticipated roll-out to production Jan 2023
 - Daily work reports, project costing, payment, etc.

E-Construction

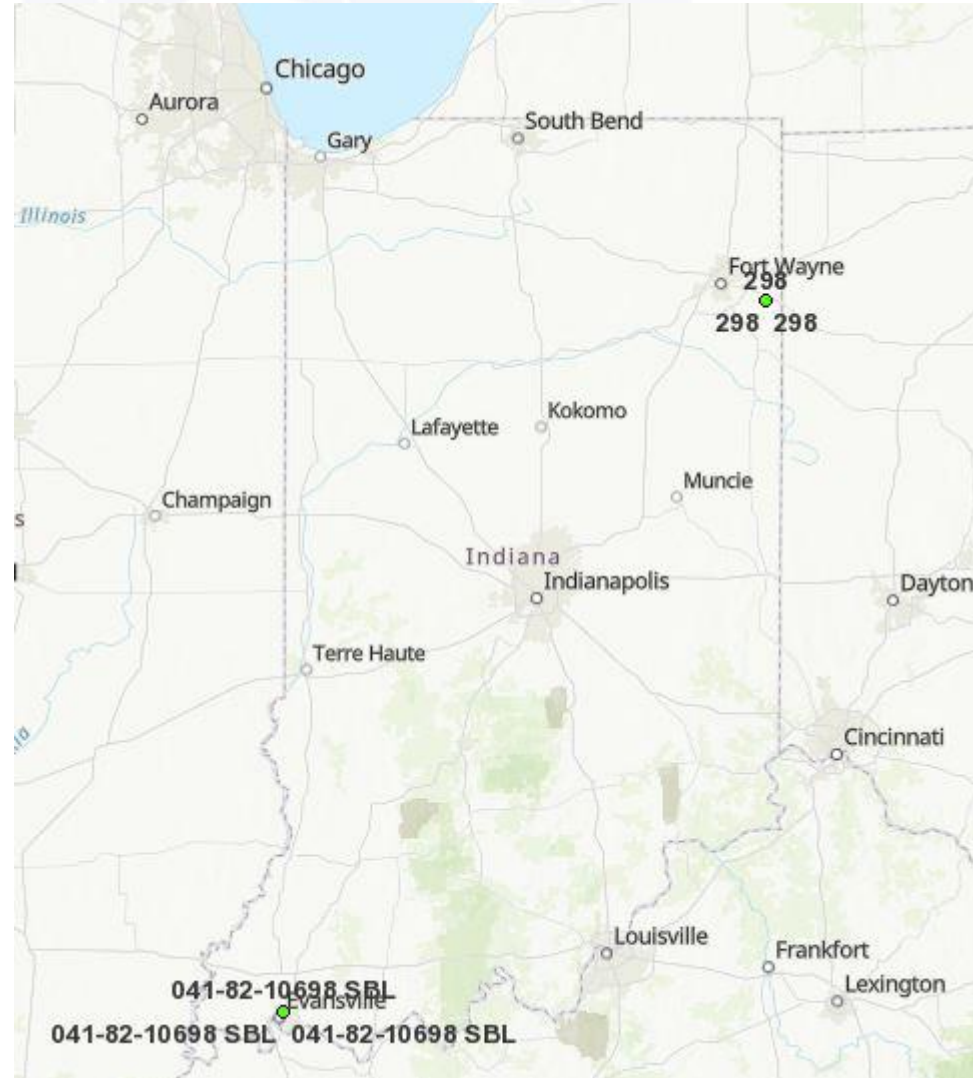
- Field Assistant Application
 - In-house developed and maintained
 - Allows construction inspection in offline mode
 - Several different modules (Daily work reports, materials, Stormwater Mgmt)
 - Provides data to AASHTO SiteManager database
 - Once AASHTOWare Project is implemented Field Assistant will be updated
- I-69 Finish Line Project
 - Piloting Autodesk BIM360
 - Construction management software from design to construction inspection
 - Mainly used as a communication tool between all parties involved, Contractor, INDOT, FHWA, etc.
 - Testing new technologies
 - 3D CAD models
 - Drone/UAS imagery,
 - GIS Asset Collection

Data Flow



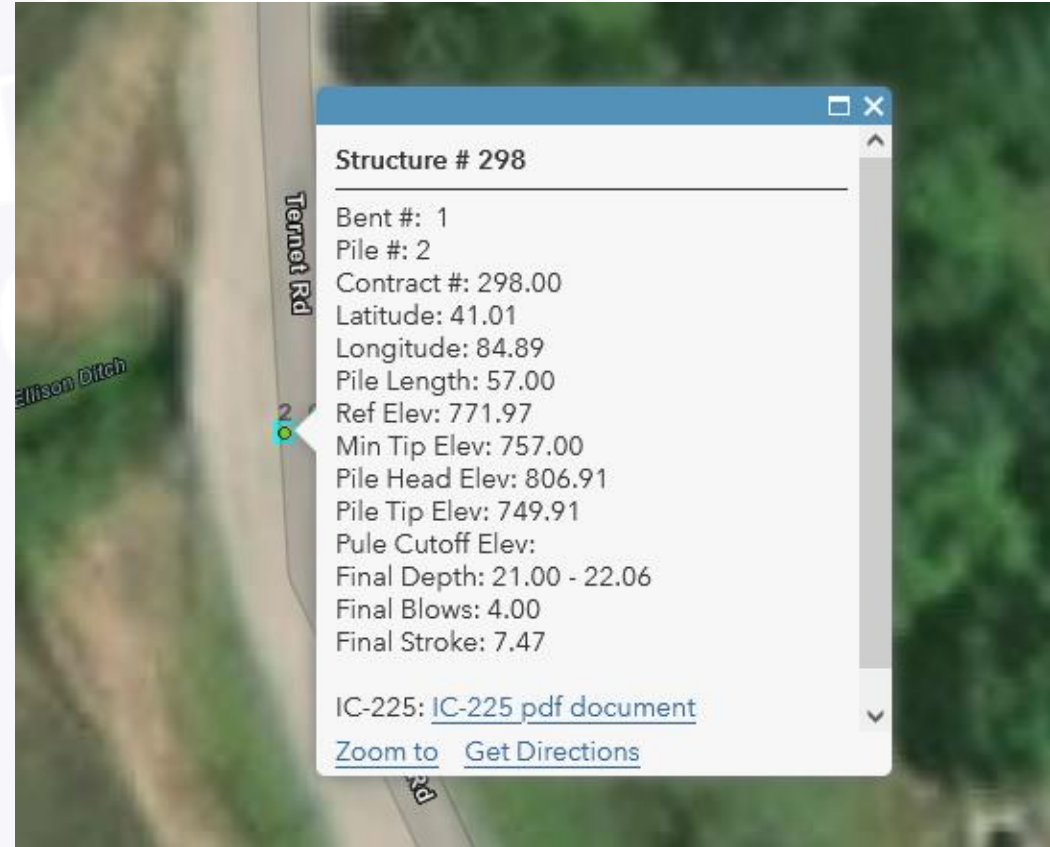
Data Flow

- Example GIS Application



Data Flow

- Example GIS Application



Future Plans

- Developed Unique Special Provisions to include Automated Pile Driving Data Acquisition Device as the data collection device for all pile driving operation.
- Selected few contracts that will be let Construction starting March 2022 as demonstration projects.
- Future tool that will greatly support data analyses for reuse of existing foundations

Future Plans

USP Highlights:

Monitoring of the piling installation shall be performed by the Contractor.

Documentation shall be submitted to the Engineer daily in accordance with 701.06(c).

The daily collected data from the driving process shall be stored and be available for use by the Engineer in real-time during the life of the contract.

The data files shall be transferred to the Department, in an acceptable format after completion of the contract for permanent storage.

USP Highlights

Documentation Required:

- Digitally produced drawing of numbered piling and location descriptions as shown on the plans.
- Time stamp with date along with start and stop times of pile installations.
- Elevation of ground at the top of the piling installation.
- Length of the driven pile.
- Blows per minute.
- Stroke for open-end diesel hammers.
- Final equivalent blow count for the last 20 blows.
- A digital copy of each day's driving operations in a non-editable electronic PDF format.

Reuse of Existing Foundation

Reuse of existing foundations is currently the biggest driver, and this may present a significant cost and time savings in transportation and building industry for structures rehabilitation efforts.

This has strong sustainability credentials.

Reduction in new concrete, steel for substructures and omission of foundation piles and pile caps.

Reuse of Existing Foundation

Availability and verification of existing foundation information:

- Foundation designer's records
- Foundation Contractor's record
- Evaluation of original/existing and proposed loading
- Evaluation of Existing Foundation Capacity with Scour
- Site investigations required to establish as-built existing foundations and site/ground condition
- Availability of ground deformations and monitoring information
- Risk Management

Acknowledgements:

- Smart Structures – Dr. Sastry Putcha
- GRL, Inc – Mr. Travis Coleman
- Mr. Kurt Pelz
- Mr. Patrick Paterson
- Mr. Athar Khan
- Mr. Min Sang Lee
- Mrs. Rhoni Oliver

Thanks!