Substructure Construction Inspection

Session 3

Learning Outcomes

Upon completion of this course participants will be able to:

- Identify the critical elements of substructure construction.
- Perform basic plan and layout checks on critical bridge substructure elements.
- Identify the equipment used for substructure construction
- Perform pile driving inspection
- Perform bar steel reinforcement inspection
- Perform concrete placement inspection

Substructure Elements

Abutments

- Piles
- Footing
- Body or Barrel
- Backwall
- Sidewalls
- Seats
- Wing walls
- Riprap/Slope Paving/Backfill

Piers

- Piles
- Seal
- Footing
- Columns
- Pier Wall
- Pier Cap
- Seats
- Riprap

Primary Substructure Evaluation Items

What to expect and inspect during substructure construction

- Erosion Control
- Excavation
- Piling
- Forms
- Reinforcing Steel
- Concrete
- Backfill
- Slope Protection

Erosion Control

Review the Erosion Control sheets within the plan set and review the ECIP.

- Silt Fence
- Erosion Bales / Ditch Checks
- Turbidity Barrier or Steel Sheeting
- Filter Bag / Settling Basin
- Riprap and Erosion Mat

Silt Fence & Erosion Bales

Erosion Bales/Erosion Mat

Installation Poor vs Acceptable

Turbidity Barrier In Place

Turbidity Barrier

Improper Installation

Steel Sheeting

Also provides relatively water tight barrier between site runoff and body of water

Settling Basin

Filter Bag

Filter Bag Over Erosion Bales

Note no sediment in ditch flowing towards stream

Riprap in Place After Excavation

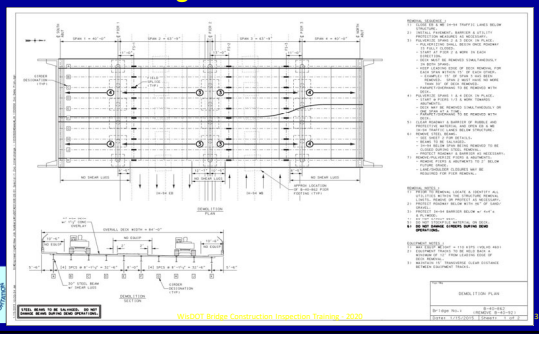
Allows for removal of turbidity barrier and adjacent silt fence

Site Preparation

- Clearing and Grubbing
- Removal of Structures
- Excavation for the Proposed Bridge

Clearing for the New Bridge

Demolition Bridge Plans



Removing Old Steel Girder Bridge

When over waterway, underdecking will be required to capture debris

Saw Cutting Old Bridge Deck

Slabbing Old Concrete Bridge

Chipping Old Concrete Bridge

Bridge Demolition

Excavation Behind Existing Abutment

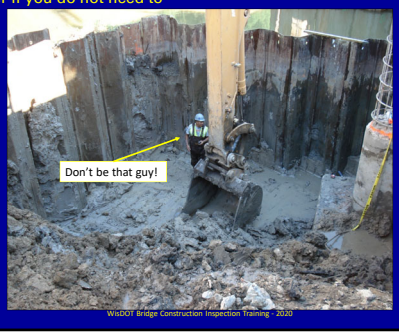
Leaving in place allows to forego turbidity barrier

Excavation Using Shoring

Used when site conditions do not allow sloping excavation

Excavating a Cofferdam

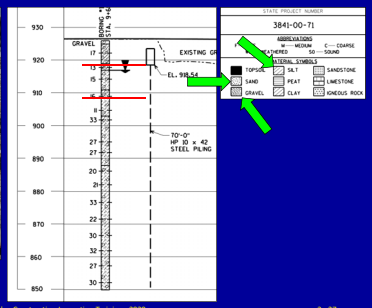
Do not enter if you do not need to



Removal of Conflicting Old Structure or Obstruction

If not in the plans, periodically note everything and everyone on site and the times

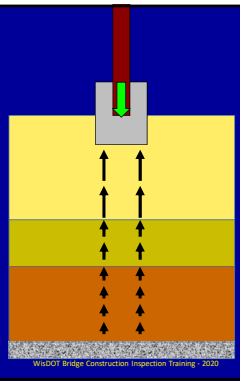
Compare In-Situ Soil Conditions to Plans



Piling

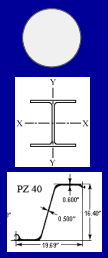
- Plan Information
- Pile Function
- Types (Cast-in-Place, H-Piles, Steel Sheeting)
- Equipment and Methods for Installation (Driving Systems)
- Documentation
- Layout
- Test Pile
- Driving
- Specifications
- Filling Cast-in-Place Piling
- Cutting & Splicing

Pile Function



Common Pile Types

- Cast-in-Place (CIP, Pipe)
- H-Piles (HP Sections)
- Sheet Piles (i.e.. MZ, PZ Sections)



Cast-in-Place Piles (CIP, Pipe, Steel Shell)

H-Piles (HP Section)

Sheet Piles

Typically used for cofferdams, shoring or dockwall applications

CIP Pile Stockpile and Welded End Plate

Make sure pile ends are not resting on earth

Check Certifications vs. Delivered Material

Piling Heat Number

Pile Layout with Old Substructure Located

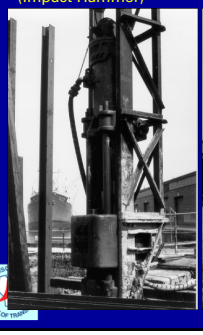
Piling Layout with Old Structure Removed

Common Pile Driving Hammers

- Air or Steam (Impact)
- Diesel (Impact)
- Vibratory

Air or Steam Pile Driving Hammer

(Impact Hammer)



Air/Steam Advantages

- Same stroke height for each impact
- Consistent operation rate
- Low impact velocity
- More efficient than diesel
- Cleaner exhaust than diesel

Air/Steam Disadvantages

- Requires Support Equipment (Compressor & Hoses & Power Source)
- Heavier

Air or Steam Pile Driving Hammer

(Impact Hammer Video)

Vibratory Pile Driving Hammer

Vibratory Advantages

- Can be used with any type of pile
- Widely used & available

Vibratory Disadvantages

- No way to asses bearing
- Requires Support Equipment (Generator & Power Lines)

Vibratory Pile Driving Hammer (Video)

Diesel Pile Driving Hammer

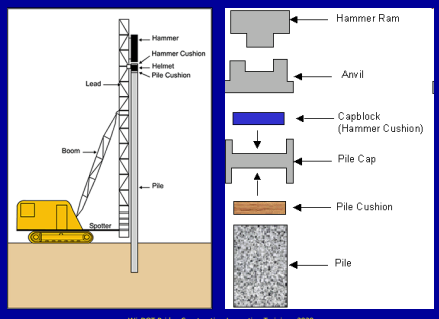
Impact Hammer: Most commonly used for bridge construction in Wisconsin.

Diesel Advantages
- Simple & dependable
- No support equipment required (built-in engine)
- Light weight vs. driving energy
- Widely used & available

Diesel Disadvantages
- Dirty exhaust

Diesel Pile Driving Hammer (Video)

Pile Driving System



Inspect the Pile Driving System

Note the jagged edges of the pile cap

Inspect the Pile Driving System

Note Buckled Pile

Knowledge Check

What are the advantages of a diesel pile driving hammer?

What are the disadvantages?

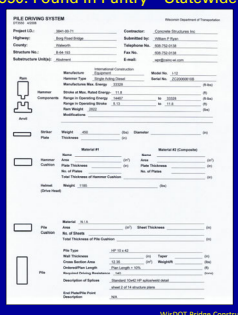
Piling Specifications

Section 550 in Standard Specs

- Capacity determined by the Modified Gates formula
  - P=(0.875 x E1/2 x log(10/s)) – 50
    - P = Nominal Resistance
    - E = Energy produced by hammer (ft-lbs)
    - s = Average penetration in inches/blow
      - (computed over max. distance of 1 inch)
- For some structures, may use Wave Equation to determine pile capacity
- Both methods result in an ultimate capacity
- Contractor must submit required drive train information and receive approval before starting driving
- Any change in drive train requires a new submittal and approval

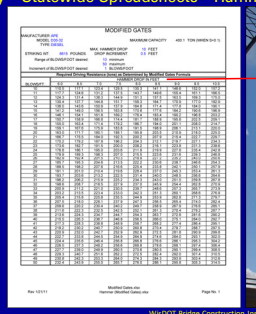
Piling Specification

DT3550: Found in Pantry – Statewide Forms



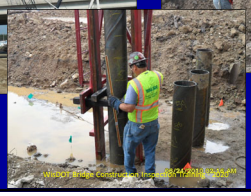
Pile Driving Hammer Data Sheet

Pantry – Statewide Spreadsheets – Hammer(Modified Gates)



Pile Driving
Determining Ram Height and Fall

Pile Driving

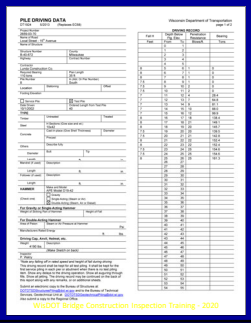


Pile Driving

Test Pile

Pile Driving Record for Test Pile

DT1924: Found in WisDOT Pantry website (Statewide Forms)



PILE DRIVING DATA

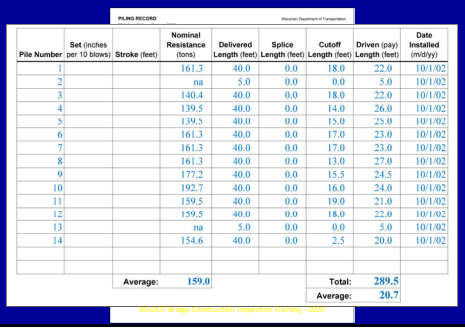
Wisconsin Department of Transportation

DRIVING RECORD

Part in Feet	Total Blows Per Foot	Penetration Per Blow	Bearing Tons
0	0	0	
1	1	1	
2	2	2	
3	3	3	
4	4	4	
5	5	4.1	0
6	6	4.1	0
7	7	4.1	0
8	8	4.1	0
9	9	4.1	0
10	10	4.1	0
11	11	4.1	0
12	12	4.1	87.7
13	13	4.1	95.0
14	14	4.1	95.1
15	15	4.1	95.1
16	16	4.1	95.0
17	17	4.1	95.0
18	18	4.1	108.4
19	19	4.1	108.4
20	20	4.1	108.4
21	21	4.1	108.5
22	22	4.1	108.5
23	23	4.1	108.4
24	24	4.1	108.4
25	25	4.1	108.4
26	26	4.1	108.5
27	27	4.1	108.5
28	28	4.1	108.5
29	29	4.1	108.5
30	30	4.1	108.5
31	31	4.1	
32	32	4.1	
33	33	4.1	
34	34	4.1	
35	35	4.1	
36	36	4.1	
37	37	4.1	
38	38	4.1	
39	39	4.1	
40	40	4.1	
41	41	4.1	
42	42	4.1	
43	43	4.1	
44	44	4.1	
45	45	4.1	
46	46	4.1	
47	47	4.1	
48	48	4.1	
49	49	4.1	
50	50	4.1	
51	51	4.1	
52	52	4.1	
53	53	4.1	
54	54	4.1	
55	55	4.1	

Piling Record

DT1315: Found on WisDOT website (Forms)



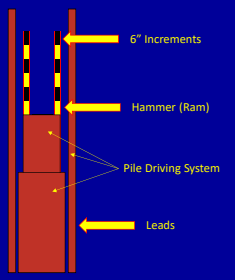
PILING RECORD

Wisconsin Department of Transportation

Pile Number	Set (inches per 10 blows)	Stroke (feet)	Nominal Resistance (tons)	Delivered Length (feet)	Splice Length (feet)	Cutoff Length (feet)	Driven (pay) Length (feet)	Date Installed (m/d/yy)
1			161.3	40.0	0.0	18.0	22.0	10/1/02
2			na	5.0	0.0	0.0	5.0	10/1/02
3			140.4	40.0	0.0	18.0	22.0	10/1/02
4			139.5	40.0	0.0	14.0	26.0	10/1/02
5			139.5	40.0	0.0	15.0	25.0	10/1/02
6			161.3	40.0	0.0	17.0	23.0	10/1/02
7			161.3	40.0	0.0	17.0	23.0	10/1/02
8			161.3	40.0	0.0	13.0	27.0	10/1/02
9			177.2	40.0	0.0	15.5	24.5	10/1/02
10			192.7	40.0	0.0	16.0	24.0	10/1/02
11			159.5	40.0	0.0	19.0	21.0	10/1/02
12			159.5	40.0	0.0	18.0	22.0	10/1/02
13			na	5.0	0.0	0.0	5.0	10/1/02
14			154.6	40.0	0.0	2.5	20.0	10/1/02
		Average:	159.0			Total:	289.5	
						Average:	20.7	

Pile Driving and Recording Exercise

Refer to Handouts and Example Plan Sheets



Fall height in barrel = 5.0'
Weight of Ram = 2822 #
Bearing Resistance= 140 Tons

How many blows/foot are required to obtain needed Bearing Resistance at current fall height?

How many blows/inch?

Pile Refusal

Pile Collapse

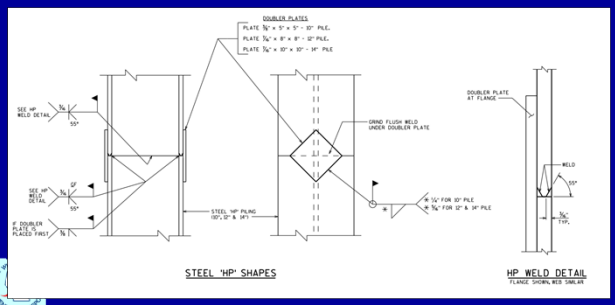
C-I-P Spiral Weld Failure

Achieving Plan Elevations for Piles

- Driving to Plan Elevation
  - Ideally, All Piles are Driven to Same Elevation (Rare)
- Splicing
  - Welding
- Cutting

Splicing H-Piles

Plan Details

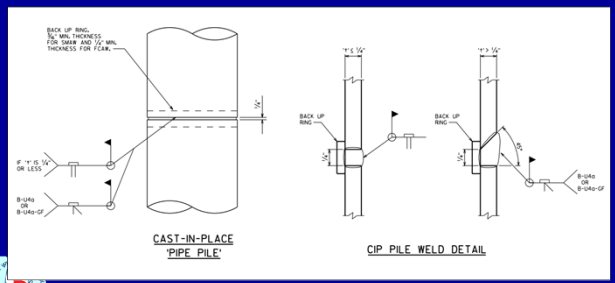


STEEL 'HP' SHAPES

HP WELD DETAIL
FLANGE SHOWN, WEB SIMILAR

Splicing C-I-P Piles

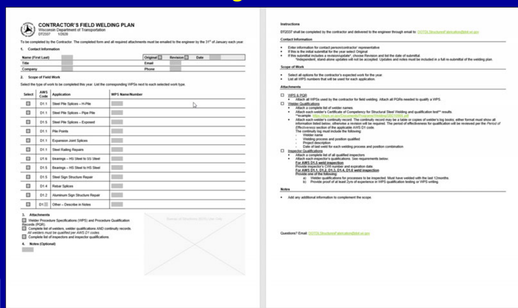
Plan Details



CAST-IN-PLACE 'PIPE PILE'

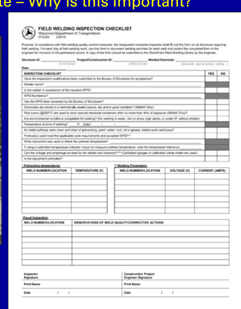
CIP PILE WELD DETAIL

Contractor Field Welding Plan



Splicing Piles

See Forms Section of WisDOT Website – Why is this important?



Splicing Cast-in-Place Piling

Backer Plate with Spacers

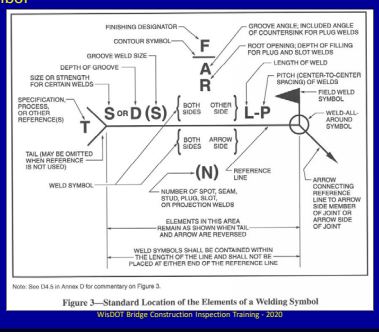
Welding

General Overview

- A joining process producing coalescence of materials by heating them to the welding temperature, with or without the application of pressure or by the application of pressure alone, and with or without the use of filler material.
  - Piling welding in the field is done without pressure
- Follows AWS D1.5 Bridge Welding Code
- Typical processes in field
  - Shielded Metal Arc Welding (SMAW)
    - A.K.A. Stick Welding
  - Gas Metal Arc Welding (GMAW)
    - A.K.A. MIG welding

Welding

Welding Symbol



Note: See D4.5 in Annex D for commentary on Figure 3.

Figure 3—Standard Location of the Elements of a Welding Symbol

Welds

The Good, the Bad and the Ugly

Spliced H-Pile - GOOD

Note good weld quality and lack of spatter

Spliced H-Pile - BAD

Note the Poor Weld Quality

Splicing Cast-in-Place Piling

Note the Poor Preparation

Splicing Cast-in-Place Piling

Note the offset and quality of weld

Can you spot the problem with this weld?

Knowledge Check

Can you spot the problem with this weld?

A. Excessive Spatter
B. Lack of Penetration
C. Lack of Fusion
D. Poorly Spaced Passes
E. Excessive Reinforcement

What to Check When Welding

Refer to Table 2 of Section 5-20 in the CMM

- Is it raining?
- Has a bevel been ground in?
- Are the surfaces free of dirt, slag or other contaminants?
- Is there an electrode oven?
  - Is the oven on?
- When did the contractor open the hermetically sealed container?
- What is the ambient temperature?
  - Preheating may be required
  - If its near freezing, preheating is recommended

Cast-In-Place Piling

Note that the piles are covered to keep debris out.

Cast-In-Place Piling

What is wrong with the piling in this picture?

Pile Driving - General Tip

Why should the inspector know there is an issue?

Pile Driving - General Tip

Battered Piles

Cutting Piling

Piling Checklist – CMM

CMM Section 1-60 Attachment 2

Recommendations After Pile Driving

- Cover tops of CIP piling
- Drop a rock
- Drop a tape
- RECORD ALL MEASUREMENTS

Cofferdam Seal

Pier in water after piling installed

Cofferdam Seal

Forming & Reinforcement of Substructure

Abutments
- Body or Barrel
- Backwall
- Wingwall

Piers
- Footing
- Pier Shaft and/or Columns
- Beam Seats

Reinforcement Stockpile with Proper Tags

Note the proper storage off of the ground and out of the mud

Rebar Testing Requirements

- Test bars provided by mill
  - These bars are not to be taken to lab for testing
  - Splice into structure, with proper lap length
- Test samples dependent on weight (CMM 8-50)
  - No test bars needed per size for total weight <50,000#
  - 2 – 5′ test bars per size per 50,000-100,000#
  - 3 – 5′ test bars per size per 100,000-150,000#
  - Etc.
- Test bars should be taken randomly preferably from differing heats

Timber Forms Constructed at Back Face

Abutment Beam Seat Forming

Note Chamfer Strips Installed at Beam Seat Elevation

Lifting Steel Cage into Place

Abutment Steel Tied into Place

Steel Forms/Reinforcement Lifted into Place

Pier Footing

Forms are installed and braced and the reinforcement tied and secured.

What needs to be done by the inspector prior to placing concrete?

What needs to be done by the contractor prior to placing concrete?

Timber Formwork for Abutment

Pier Wall Wood Formwork

What checks should the inspector be making on the forms & reinforcement?

Cap Concrete Pour with Bucket

Note wood chamfer strips used to set top elevation of cap and beam seats

Pouring Abutment

Note layering concrete across abutment

Finished Abutment Seats

Cap Concrete Pour

Note wood chamfer strips used to set top elevation of cap and beam seats

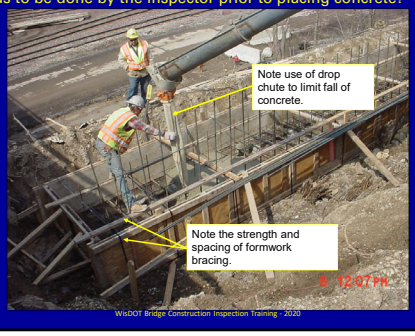
Concrete Curing

- Ideally concrete is given enough time to cure before form removal
  - This is rarely the case
- The Contractor should immediately begin finishing concrete upon form removal
- If there is an anticipated delay in surface rubbing
  - Dissipating curing compound should be placed immediately upon all surfaces that will not be incorporated in further pours.
  - Typically compound remains on surface for 30 days, if rubbing prior to this, contractor should water blast the surface.

Abutment Stripped of Forms

Sill Abutment w/ Backwall Concrete Placement of Footing

What needs to be done by the inspector prior to placing concrete?



Sill Abutment Footing

Note Keyway and Rough Concrete @ Joint

Sill Abutment Body

Note Keyway and Rough Concrete @ Joints

Wrapped Pipe Underdrain

What should the inspector check with the drain?

Wrapped Pipe Underdrain

Make sure it daylights

Rubberized Membrane Waterproofing

Pier Shaft/Column Reinforcement

Check rebar size, spacing, and lap lengths

Wingwall Steel Tied

Should the inspector be concerned with anything in this photo?

Pier Shaft/Column Steel Formwork

What checks should the inspector be making on the forms?

Pier Shaft/Column Steel Formwork

What checks should the inspector be making on the forms & reinforcement?

Pouring Wingwalls

Sill Abutment Backwall/Wingwall

Note Utility Box Out and Joint Seal

Concrete Curing – Dissipating Cure

After rubbing/finishing concrete

Common Concrete Temperature Protection Methods

- Blankets
- Preheating Formwork
- Heating Mix in Cold Weather
- Icing Mix in Hot Weather
- Burlap / Plastic Covering

Blankets for Cold Weather Protection

Check "R" Rating of Protection

Preheating Formwork

Plastic Cover for Top of Abutment

Preparing for Riprap Placement

Ensure riprap toe is properly excavated

Riprap Placement

Stone later epoxied

Riprap Placement

Riprap Placement

Backfilling Abutment with Slurry

Refer Plan Notes Regarding Backfill Limits Prior to Superstructure Placement

Backfilling Abutment with Structural Backfill

Note Standard Specs / Provisions / Materials Diary for testing requirements

Backfilling Pier

What items should the inspector be checking?

Mechanically Stabilized Earth (MSE) Walls

What needs to be done by the inspector prior to placing concrete?

MSE Wall – Footing Installed

MSE Wall

MSE Wall – Placing First Row of Panels

What needs to be done by the inspector prior to placing panels?

MSE Wall – Panel Plumb Check

Discrepancies will magnify the taller the wall

MSE Wall – Panel Row Installed

First row of panels of MSE Wall installed

MSE Wall – Drainage and Joint Sealing

Fabric at panel joints allows moisture seepage but no loss of fill

MSE Wall – Strap Layout and Fill Compaction

What needs to be done by the inspector during fill placement?

Problems We Do Not Want to See!

Dirty Rebar

Too Much (Little) Concrete Cover

The same concern applies for lap splices of rebar

Reinforcement Clearance Issues

- No "burning" bars
  - When rebar is touching formwork
  - Rebar typically 2" clear from all surfaces unless noted otherwise in the plans
- Too much rebar clearance
  - Without reinforcement, concrete may crack, delaminate and spall off or not function as intended

Poor Concrete Consolidation on Diaphragm

Poor Concrete Consolidation on Wing

Poor Concrete Consolidation on Column

Poor Concrete Consolidation on Beam Seats

Cracking Around Utility Box Out

Inspector Vigilance

Things to keep an eye on in the field

- Water added to concrete trucks
  - Note the amount and where the load is placed
  - If load being tested, must be tested AFTER water added
  - Inspector may request concrete tested when deemed necessary
- Improper concrete vibrating technique
  - Always inserted and removed vertically
  - Slow and controlled
  - Vibrator must penetrate the previously placed layer
- Queued concrete trucks
  - Note when trucks arrive and start and end discharge
    - Without WR – 60 minutes from batch
    - With WR – 90 minutes from batch
- Reinforcement spacing and clearances

Substructure Construction

EXERCISES

Exercise Questions

1.) Where do you find the required bearing resistance values of the piling?

Foundation data sheets and with each footing unit in the plan.

2.) What happens when piling tightens up quickly and you cannot count a whole foot as it is being driven?

Have the contractor mark the piling every 10 blows. Equate measurement to table to find bearing. Continue until acceptable bearing is achieved.

3.) Do different piling types require different pile driving caps?

Yes, each shape requires a different cap. The pile cap must fit the configuration of the pile.

Exercise Questions

4.) A pile reaches bearing after driving it down 6 feet, and the pile next to it reaches bearing when driven down 40 feet. What action might you take in this instance?

- Contact BOS.
- Pull up the pile driven to 6 ft and move it over 2 feet toward the closest pile driven to the proper depth.
- Check soil borings and removal plans for obstruction.
- If it is only 6 ft you may want to dig down to find the obstruction.
- Document all changes

5.) Steel piling starts to bend. What do you do?

STOP! Most likely reached refusal and required bearing.

Exercise Questions

6.) The contractor is driving piling with a diesel hammer in a sensitive urban area. What precautions might you suggest to the contractor?

- Contain any exhaust spray or contaminants. For example a curtain that encloses the hammer.
- Restrict pile driving hours.
- Notify the public before starting
- Document condition of adjacent properties

7.) Exercise – Find your bearing chart

- Find the Modified Gates bearing chart
- Complete the pile driving record, and bearing report