Prestressed Concrete Piles for the Key Royale Bridge

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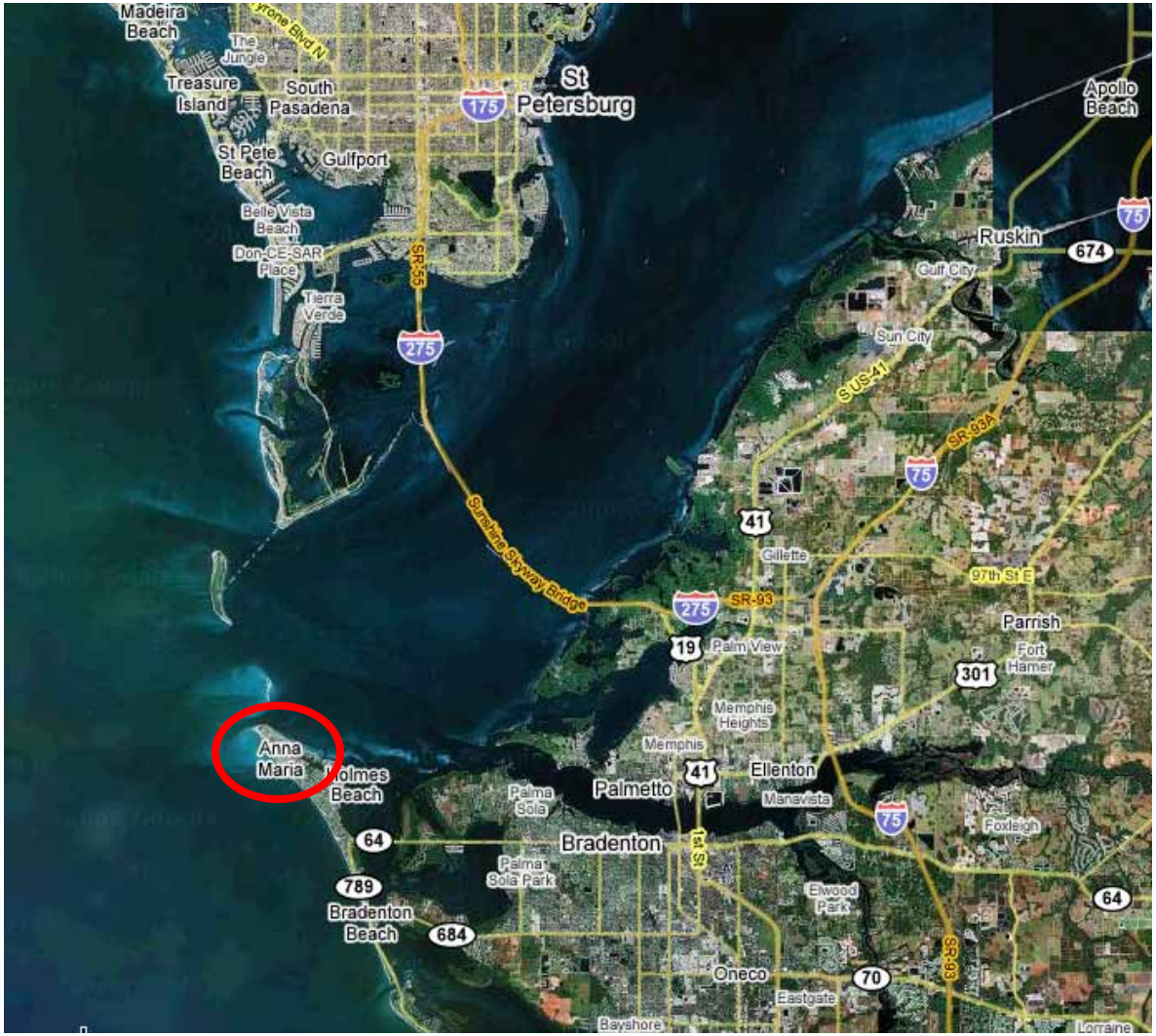
Overview

- Innovative Bridge Research and Construction (IBRC),
- FHWA provides funds to incorporate:
  - Innovative materials
  - Pioneering technologies
- Into REAL bridge projects

Location of the Bridge



Overview

- Project: Key Royale Bridge Replacement, Sarasota, Florida
- Owner: FDOT District I,
- Contractor: Cone and Graham, Inc.

- IBRC Manager: Charles Ishee, State Material Office
- IBRC Project Coordinator: University of Florida
- Pile Fabrication: DuraStress, Inc.

Objective

- Improve durability of prestressed concrete piles placed in marine environments

Improve Durability

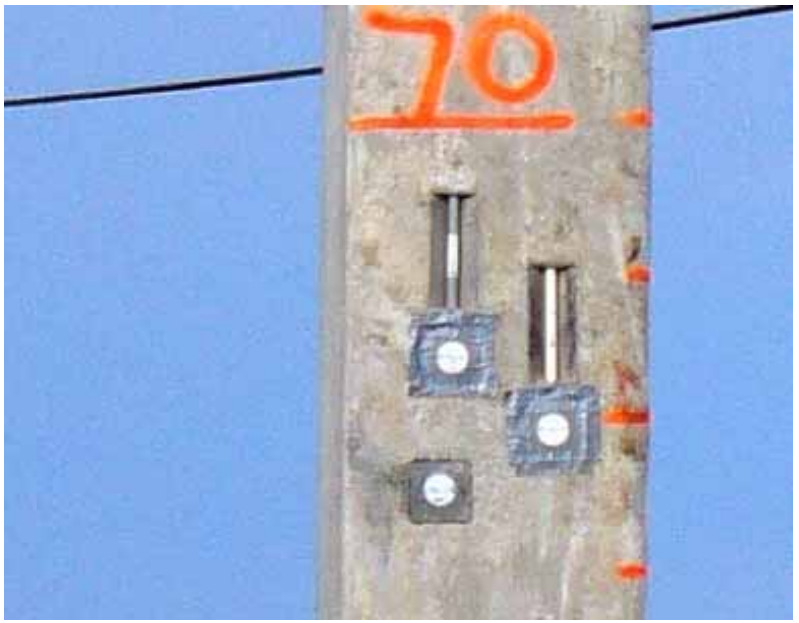
- Mineral Admixtures
  - Reduce permeability
  - Maintain strength and workability

Mineral Admixtures

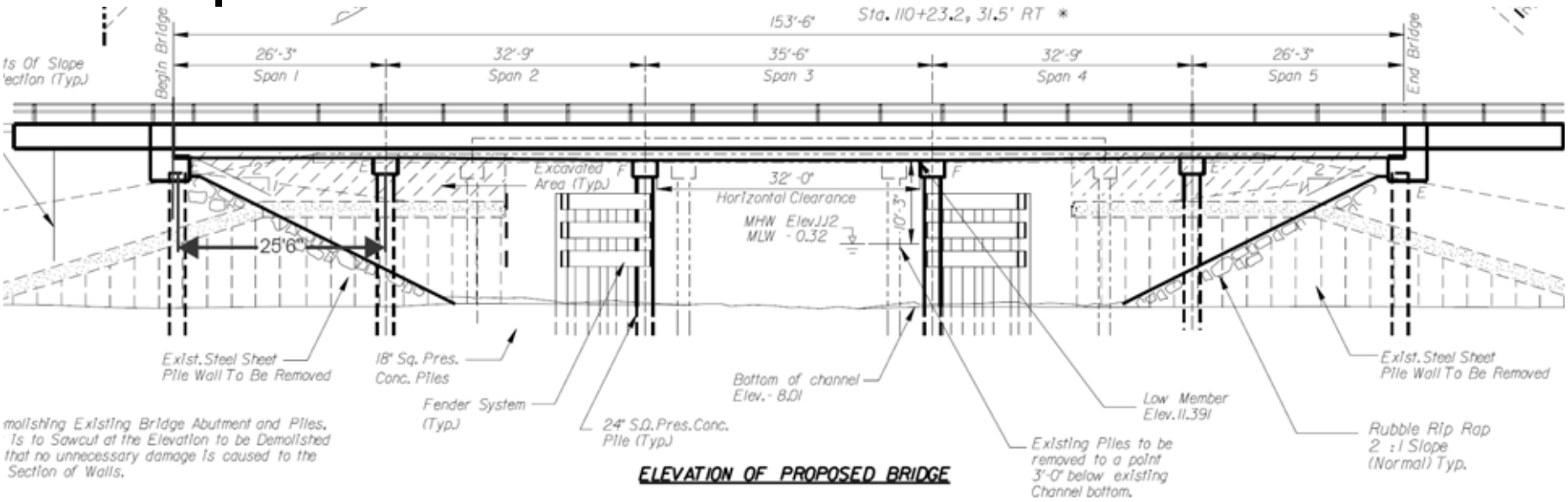
- Fly ash (FA),
- Ultra-fine fly ash (UFA),
- Ground granulated blast furnace slag (BFS),
- Metakaolin (MET),
- Silica fume (SF).

Secondary Objective

- Evaluate the use of wireless embedded sensors for monitoring of pile driving stresses,
- Different approach than typical monitoring of pile capacities and integrity (Pile Driving Analyzer - PDA).



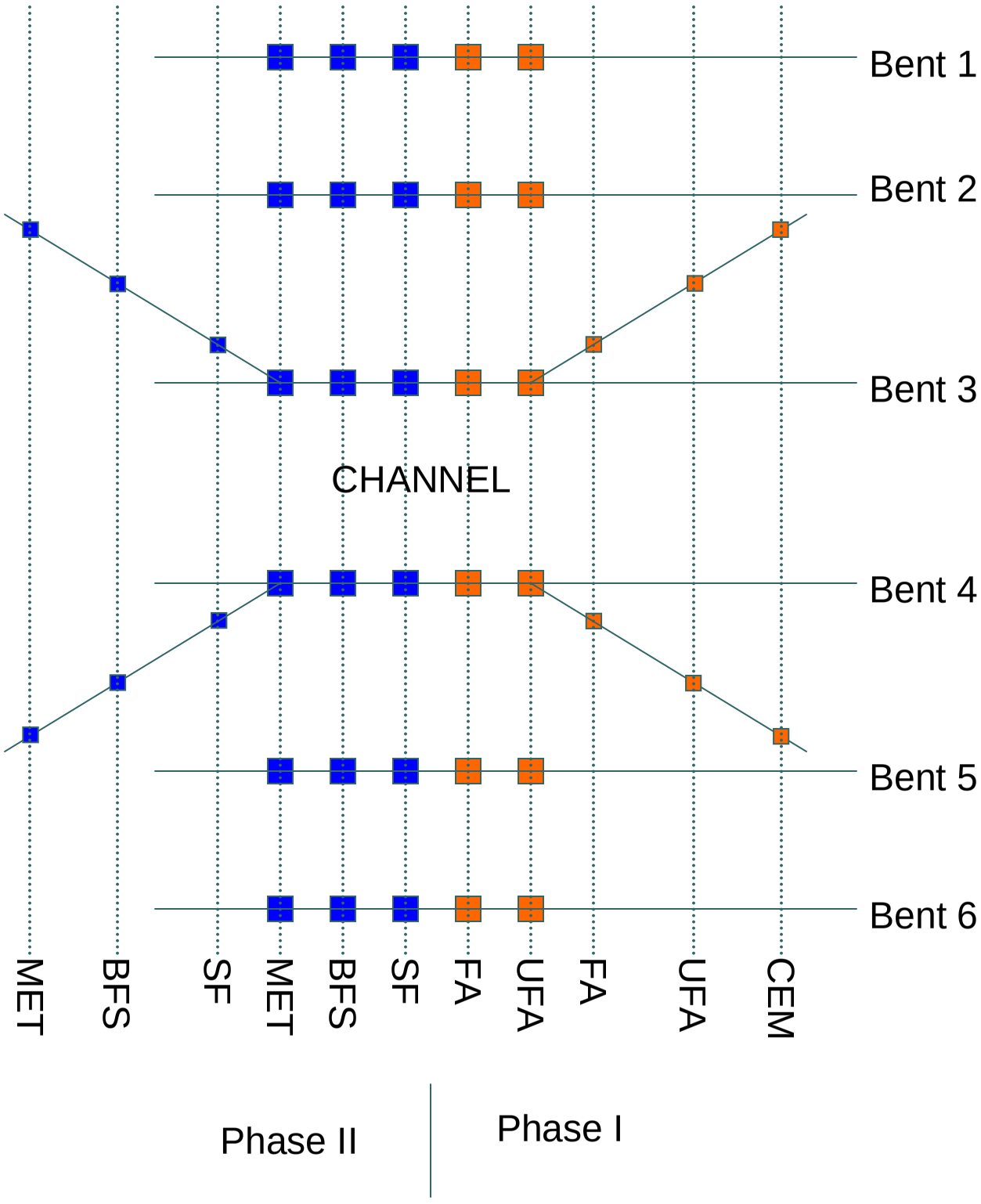
Overview of the bridge - elevation



Overview of the bridge

Full Scale Evaluation

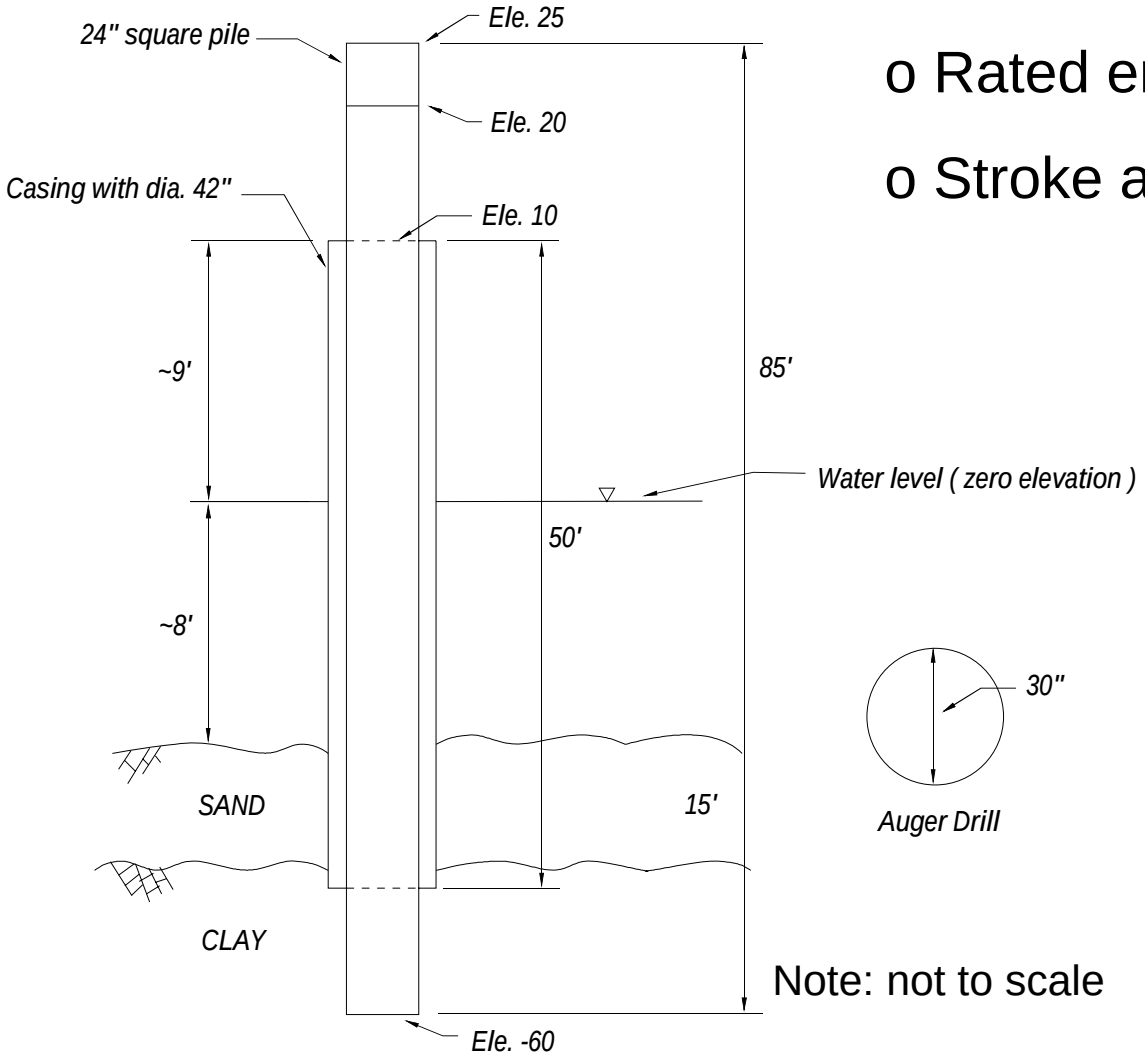
- Effectiveness at full scale,
- Lab samples do not fully represent the real structure:
  - Different production, compaction and size,
  - Samples not subjected to driving stresses.
- 5 groups of piles are made of experimental mixes (with improved impermeability) to test material behavior in full scale


Bent 1
Bent 2
Bent 3
CHANNEL
Bent 4
Bent 5
Bent 6
MET
BFS
SF
MET
BFS
SF
FA
UFA
FA
UFA
CEM
Phase II
Phase I

Full Scale Evaluation

- Corrosion monitoring by means of embedded corrosion sensors,
- Additional 5-ft segments (with corrosion sensors) are attached to the piles in the splash zone.

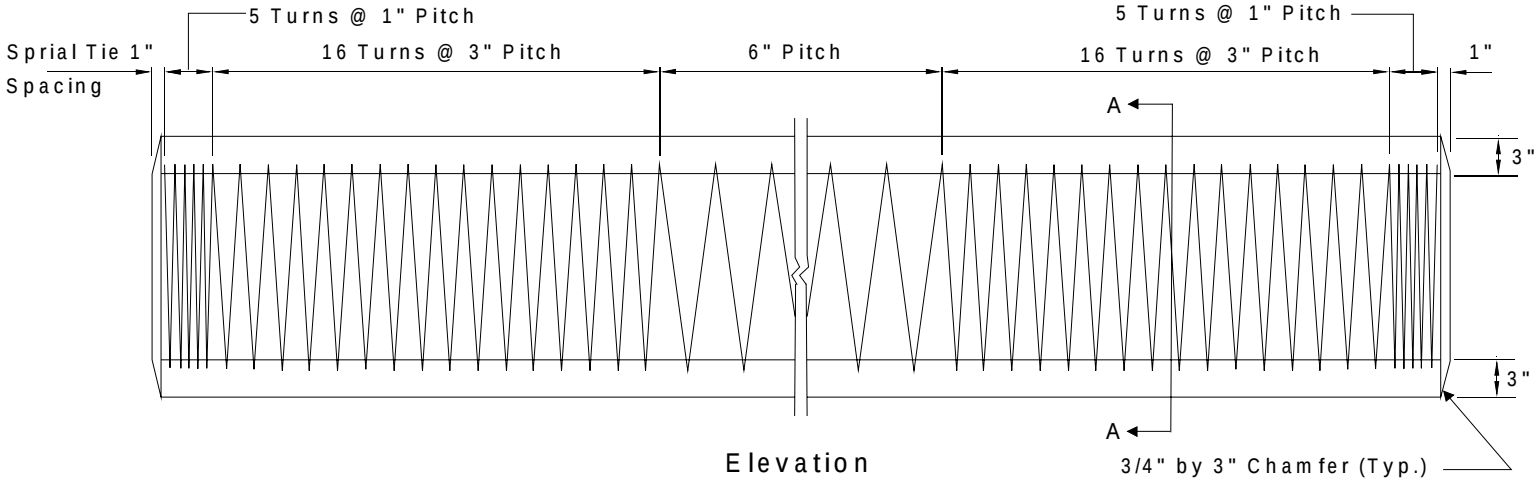
Pile Installation

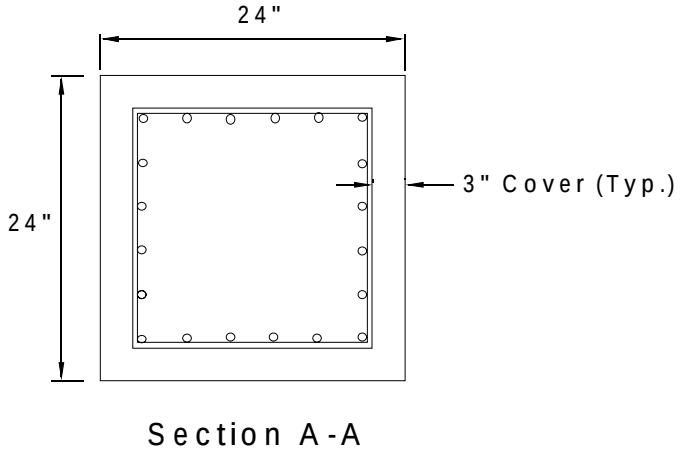


Note: not to scale

- Hammer type: ICE I-46,
- Rated energy: 107,700 ft-lbs,
- Stroke at rated energy: 10.62 ft

Piles - design





- 24-in square piles,
- 20 strands of ½ -in Φ
- 34 kips prestress on each,
- Precompression of 1000 psi
- Concrete: 6000 psi (28 days)

Relative Mineral Admixture Properties

Material	Producer	CEM	FA	SF	MET	UFA	BFS
Cement	Suwanee American	100	82	74	72	70	42
Fly Ash	ISG	0.0	18	18	18	18	18
Silica Fume	Force 10000D (Grace)	0.0	0.0	8	0.0	0.0	0.0
Metakaolin	Optipozz	0.0	0.0	0.0	10	0.0	0.0
Ultra Fine Fly Ash	Boral (Micron3)	0.0	0.0	0.0	0.0	12	0.0
GGBFS	Civil & Marine	0.0	0.0	0.0	0.0	0.0	40

Relative cement content

Mineral Admixtures Costs

Material	Price Per Ton ($/Ton)	Normalize Cost
Cement	95	1
Fly Ash	42	0.44
Silica Fume	90	0.95
Metakaolin	480	5
Ultra Fine Fly Ash	1000	10.5
GGBFS	600	6.3

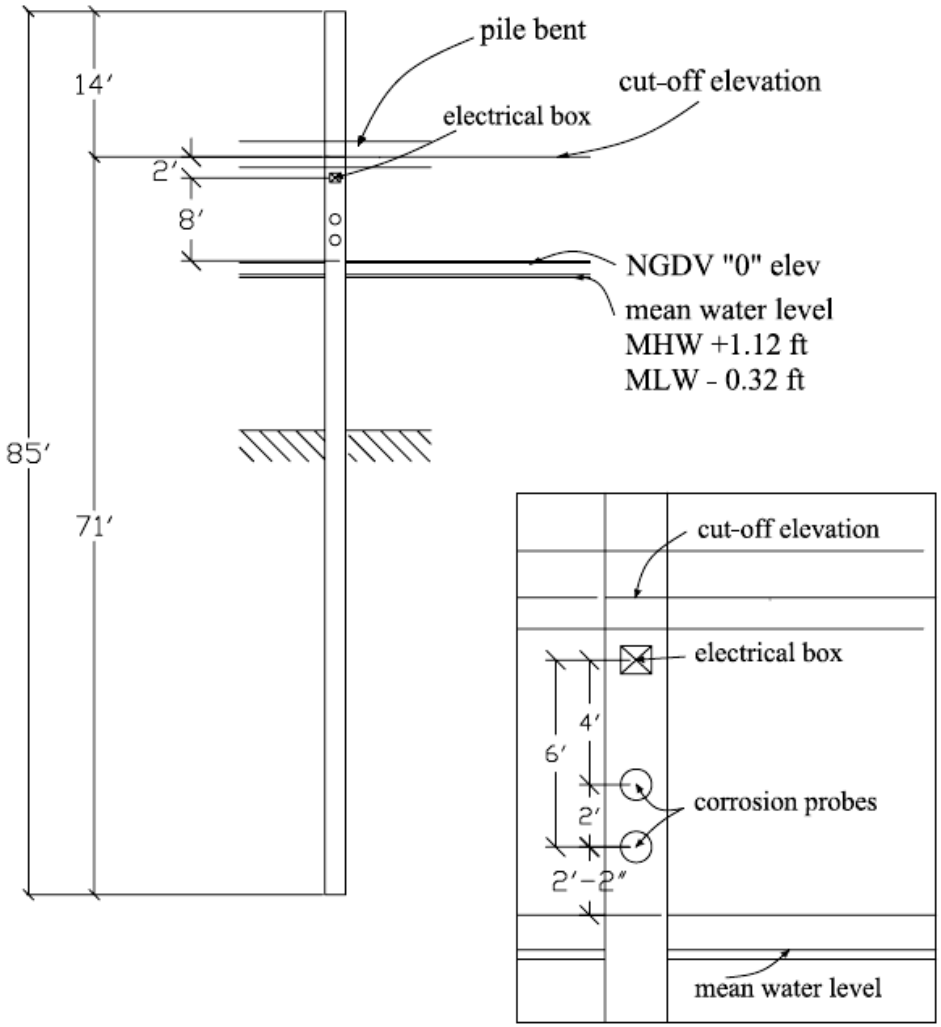
Compressive strength of cylinders (ASTM C 39-04a)

	Compressive strength at time of prestress application [psi]	7 day average compressive strength [psi]	28 day average compressive strength [psi]
CEM	N/A	N/A	6,729
FA	4,091 (4 days)	5,891	7,781
SF	5,212 (3 days)	6,707	8,044
MET	4,179 (5 days)	5,730	6,542
UFA	4,150 (3 days)	4,936	7,552
BFS	4,591 (3 days)	5,078	7,564

Concrete characteristics

- Compressive strength:
  - 6000 [psi] minimum at 28 days,
  - 4000 [psi] minimum at time of prestress application (at 3 or 4 days from pour)
- Excellent workability,
- No special treatment for handling and driving.

Corrosion monitoring



- o Corrosion probes,
- o top – titanium rod,
- o bottom – steel rod.

Testing Instrumentation

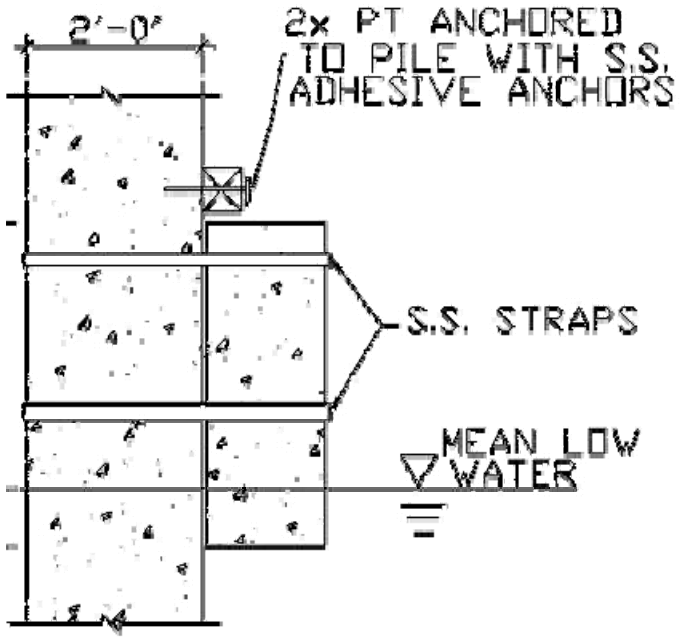
- Embedded potential sensors - titanium and steel rods,
- Natural potentials of embedded probes constant until corrosion starts,
- Change of trend in potential readings will indicate onset of corrosion,

Durability segments

- with corrosion probes and temperatures sensors,
- same concrete and strand as the fender piles.

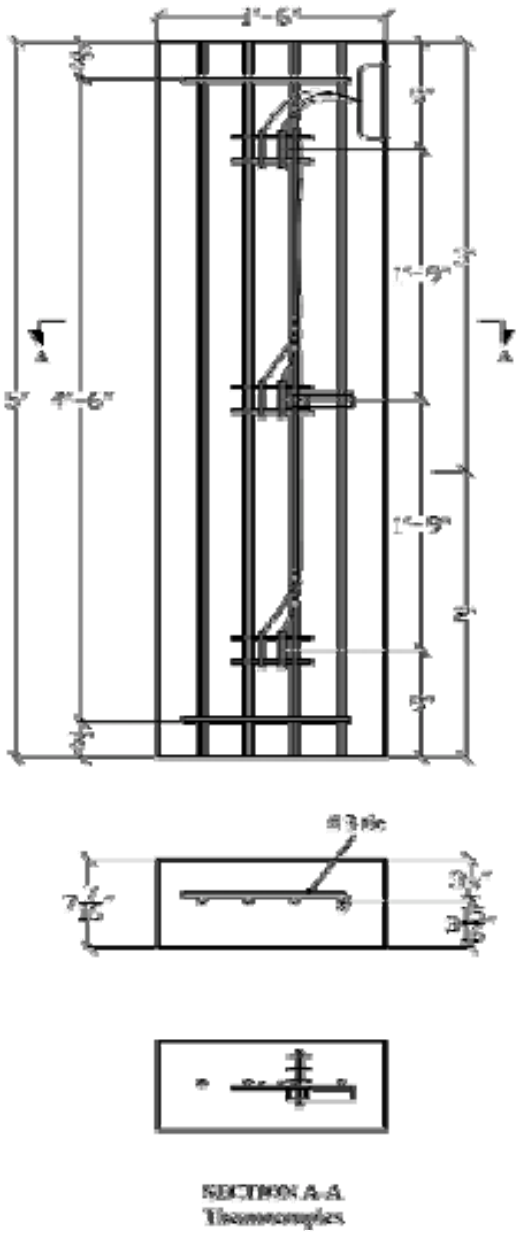
Durability segments

- can be sectioned and analyzed for corrosion
- consistent instrumentation locations among the mixes



Durability segments

- Embedded potential sensors - titanium and steel rods,
- Sensors measure corrosion potential on steel strands,
- Changes of concrete in the cover zone inferred from temperature gradient (3 embedded thermocouples),
- Temperature effect on diffusion.



Pile Driving Analyzer (PDA)

- Experimental technique to determine:
  - Axial load capacity,
  - Piles integrity,
- Based on dynamic analysis:
  - One-dimensional wave propagation,
  - Input data from strain gauges and accelerometers mounted on the top of the pile

PDA Technology:

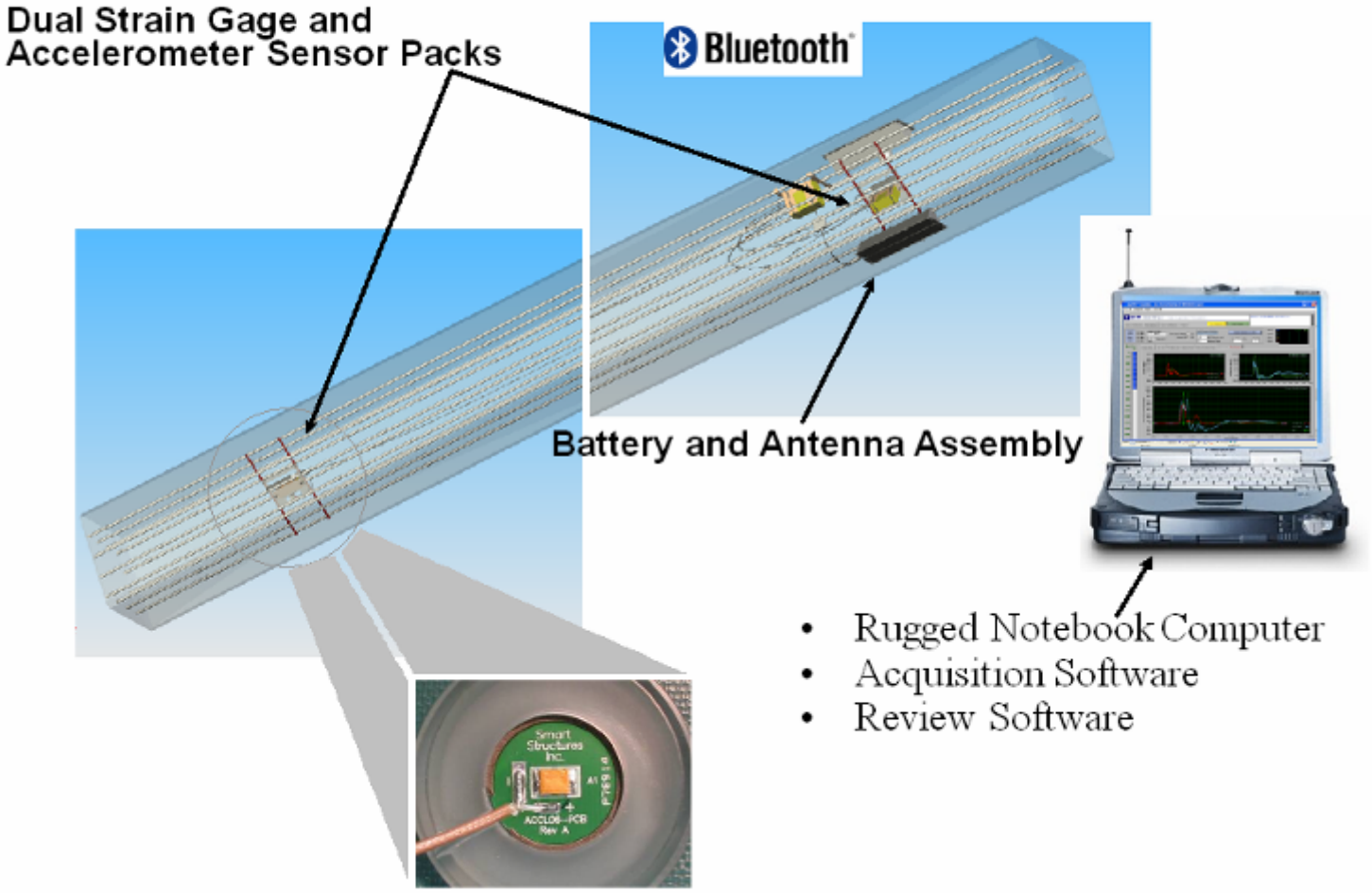
- Gages are attached after the pile leads are in place and removed prior to the leads being removed

- To attach and detach the gages someone must climb the leads

Smart Sensors

New Technology:

Wireless Networking Based on BluetoothIndustry Standard

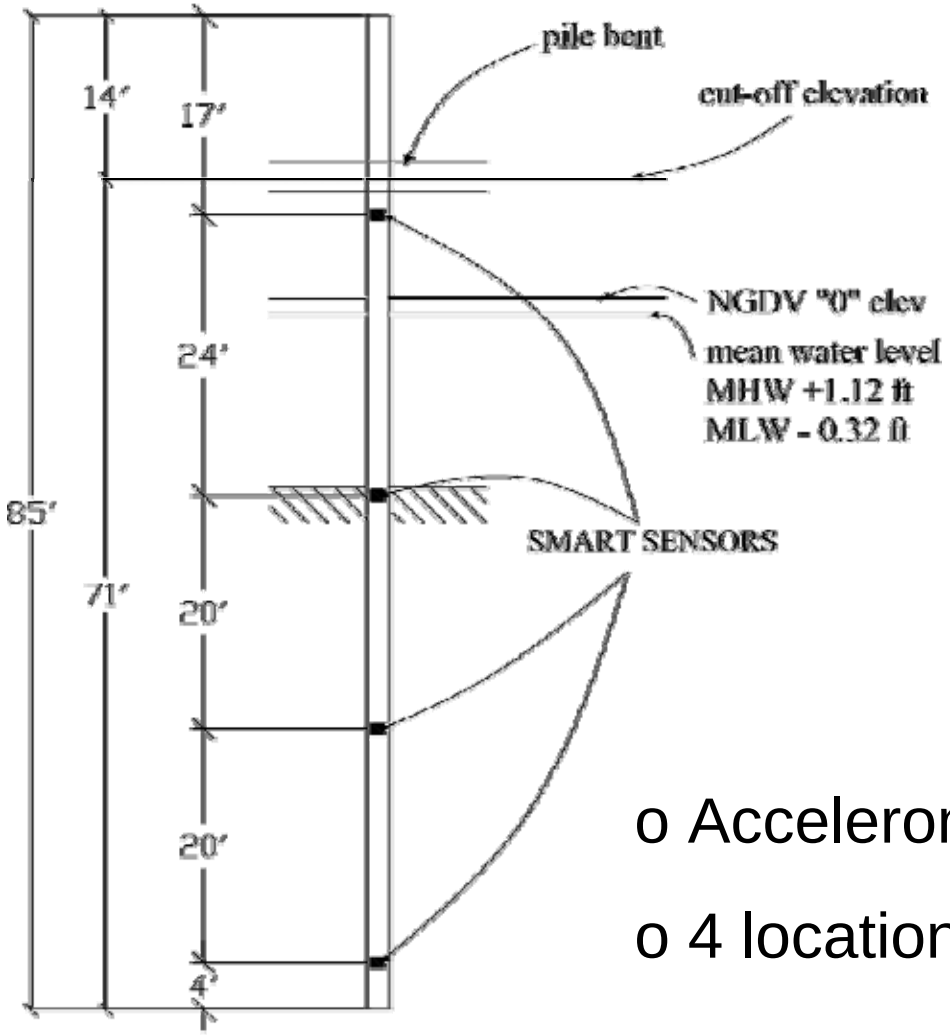


- Rugged Notebook Computer
- Acquisition Software
- Review Software

Smart Sensors

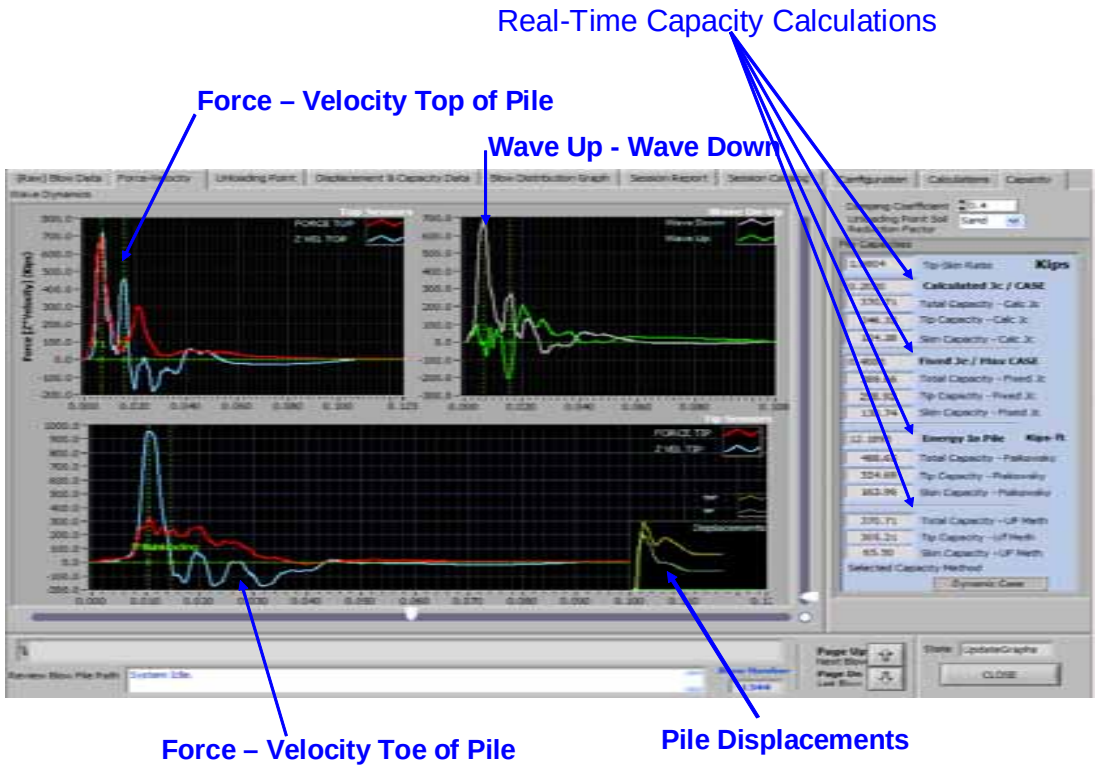
- Sensors are installed in the prestress yard
- After concrete is poured, only antenna is visible on the surface

Embedded wireless instrumentation



- Accelerometers and strain gauges,
- 4 locations in contrast to 1 (top) of PDA

Wireless data acquisition



- Real-time capacity calculations
- Pile displacements

Wireless monitoring

Summary

- Incorporating highly reactive mineral admixtures – piles in salt water,
- Collect driving data and possibly future data with smart sensors
- Allow future corrosion and temperature monitoring