S
E
C
T
I
O
N

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES SEABROOK, NEW HAMPSHIRE

Siamac Vaghar, PE

Geotechnical Engineer

and

Francis Fung, PE

Structural Engineer

US Army Corps of Engineers, Concord, Massachusetts

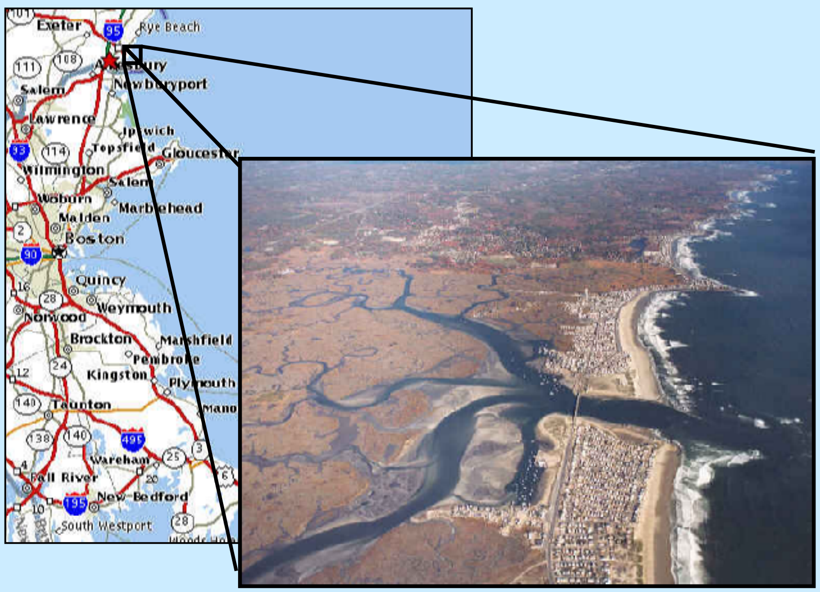
SECTION 227

Authority: Section 227 of the Water Resources and Development Act of 1996 (WRDA 96); Administered by ERDC

- **Research & Development: Advance the state of the art of coastal <u>erosion control</u> technology**
- **Encourage and achieve the development of <u>innovative</u> solutions to the erosion control challenge**
- **<u>Communicate</u> findings to the public, state, and local coastal managers**

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

Hampton-Seabrook Harbor, adjacent to the mouth of the Blackwater River, located in coastal New Hampshire, USA



DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

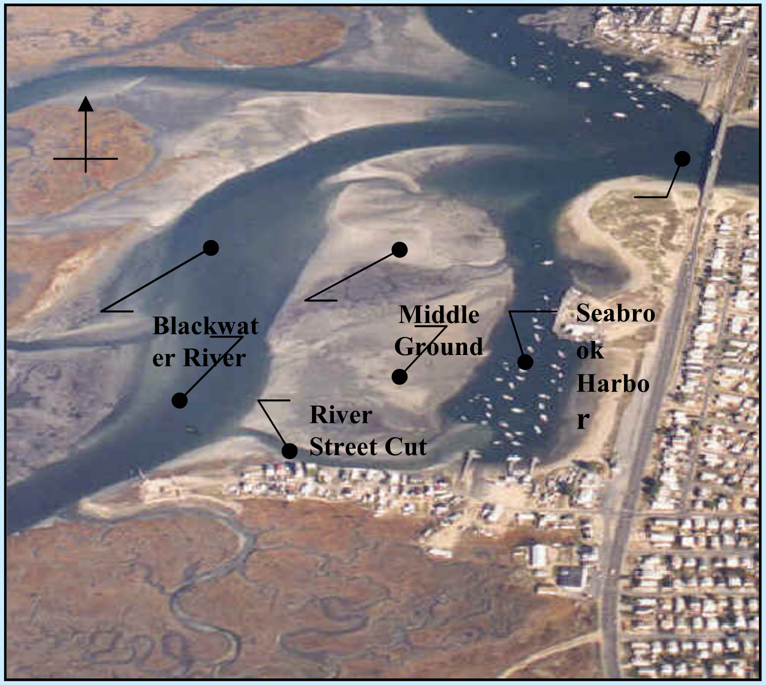
227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

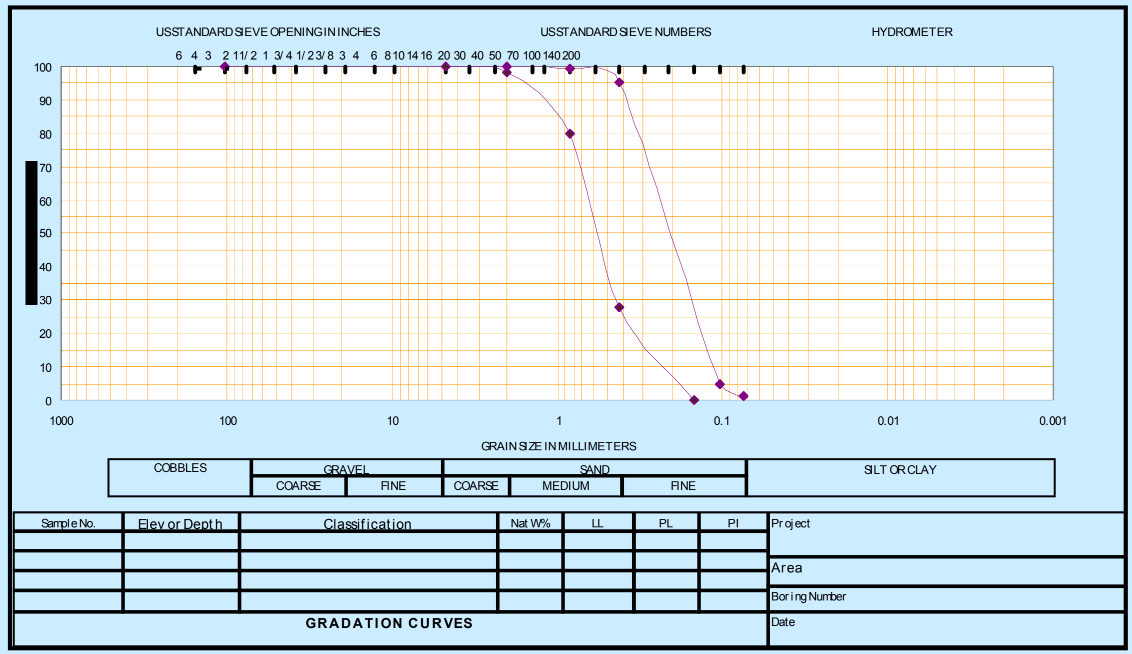
SECTION

227

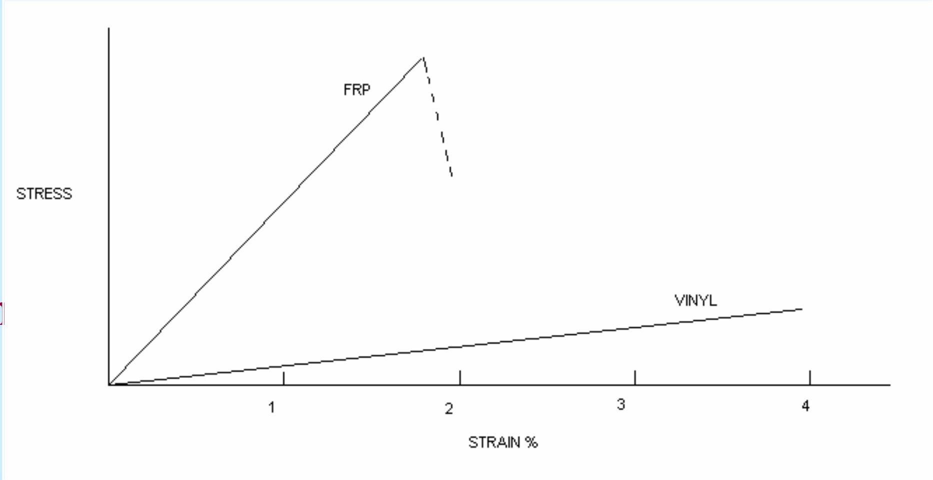
- Objectives:
  - Replace lost intertidal sands
  - Reduce sand migration into the Harbor
  - Prevent shoreline erosion
- Constraints
  - Innovative Components
  - Ability to remove
  - Dredging window of time, November through March
  - Cost
  - 50-year design life
- Solutions:
  - Install cofferdams across the eroded channel using synthetic sheeting
  - Dredge sand from the shoaled areas of the River to encourage flow
  - Use the dredged sand to fill between the cofferdams to restore the sand flats



- **Subsurface Conditions**
  - **Medium dense fine sand**
  - **Field SPT = 20**
  - **No obstructions**



- Synthetic Sheeting
  - Vinyl: Made of virgin or recycled plastic or combination (recycled, with virgin veneer)
    - High tensile strength
    - Less brittle
    - 10+ years of case histories of use
  - Fiber Reinforced Polymer (Fiberglass) Glass fibers embedded in resin matrix such as polyester, polyurethane, or vinyl ester.
    - High flexural strength
    - More brittle
    - Limited number of projects

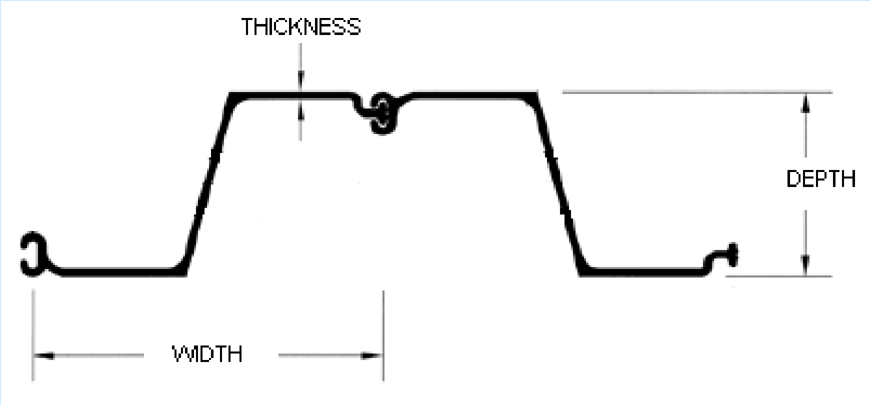


DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

Property	Test Method	Vinyl	FRP Longitudinal*	FRP Transverse*
Tensile Strength (psi)	ASTM D638	6,300	60,000	10,000
Tensile Modulus (psi)	ASTM D790	380,000	4,000,000	1,000,000
Width (inch)		18	18	
Depth (inch)		12	8	
Thickness (inch)		0.65	0.25	
Weight (lbs/sf)		8	4	

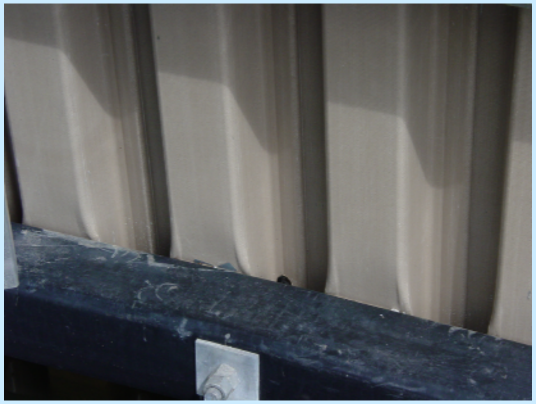


Note: Longitudinal (along) and Transverse (across) refer to fiber direction.

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

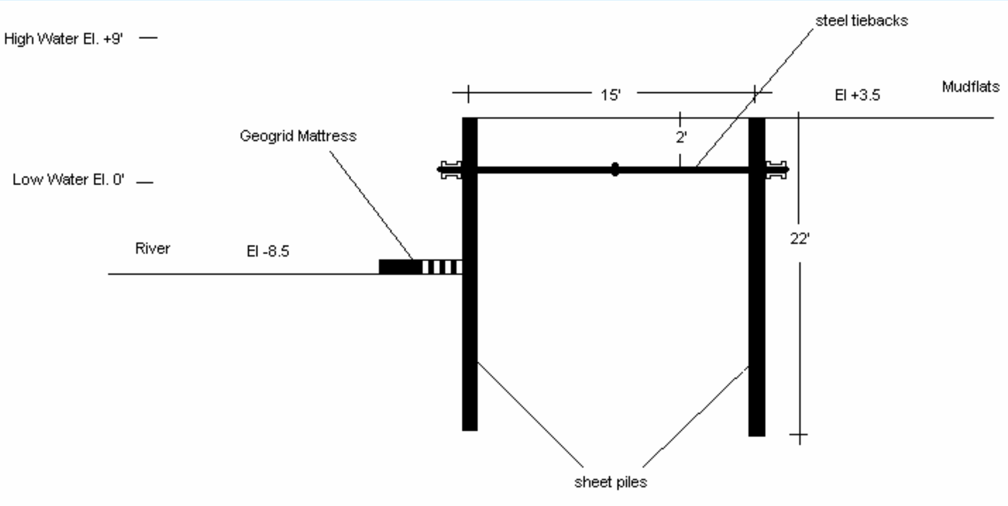
SECTION 227

- **Design Considerations**
  - Inadequate shear strength or section depth
  - Lack of interlock strength
  - Limitation on cantilevered length: recent failures during construction
  - Longevity: UV resistance, cold
  - Lack of standardized tests, data and guide specifications
  - USACE Engineering & Construction Bulletin, 2002-31 October 2002:



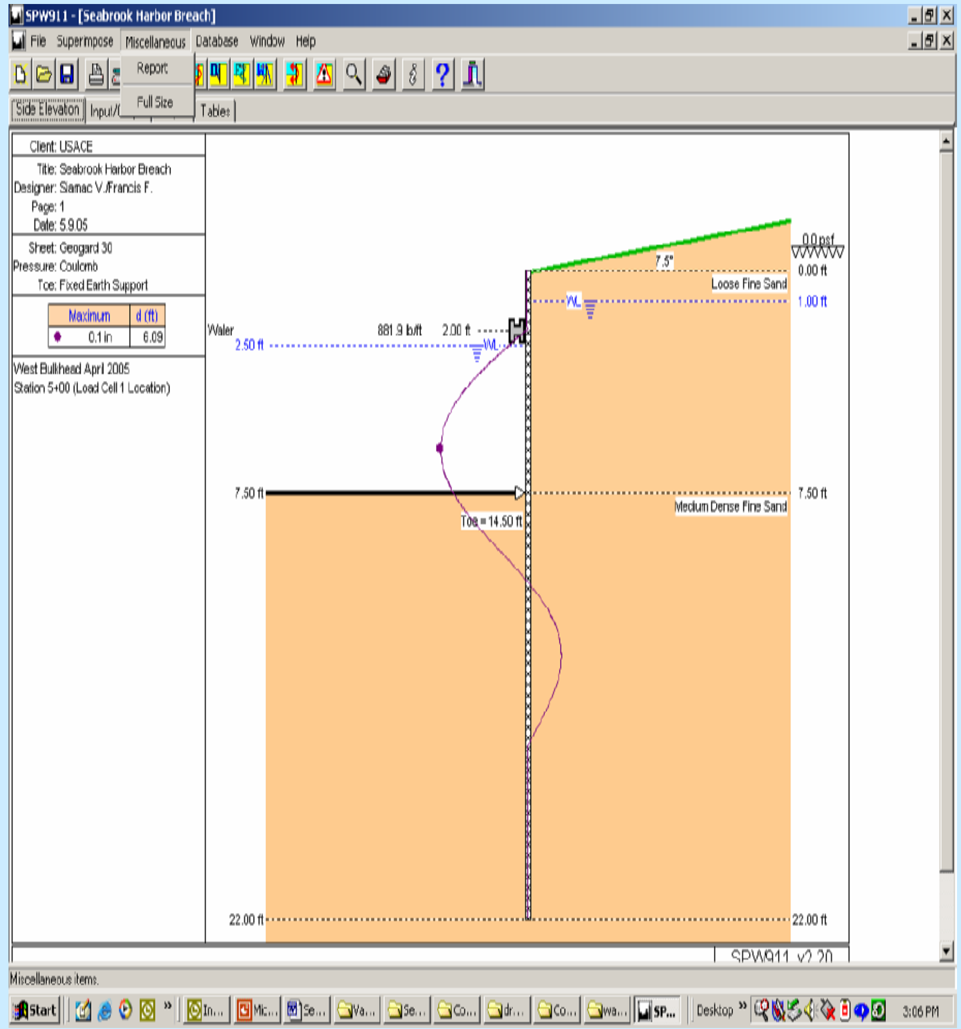
for use. In the meantime, vinyl sheet piling should not be used in applications where life safety and widespread property damage are at stake in the event of failure.

- **Selected Design for each of the two bulkhead**
  - **Double rows of sheets, FRP or heavy vinyl: No cantilever**
  - **Galvanized steel tiebacks and waler: Reliability**
  - **Single Waler: No diving (winter)**
  - **Scour protection: Protect toe**
  - **Drain holes: Reduce loads**



- Design Parameters

  – 50-year low tide
  – 50% drainage in fill
  – 12’ depth to mudline (22 feet sheet length)
  – 2 tons horizontal load per linear foot
  – Tiebacks 6’ spacing
  – 200 psf surcharge

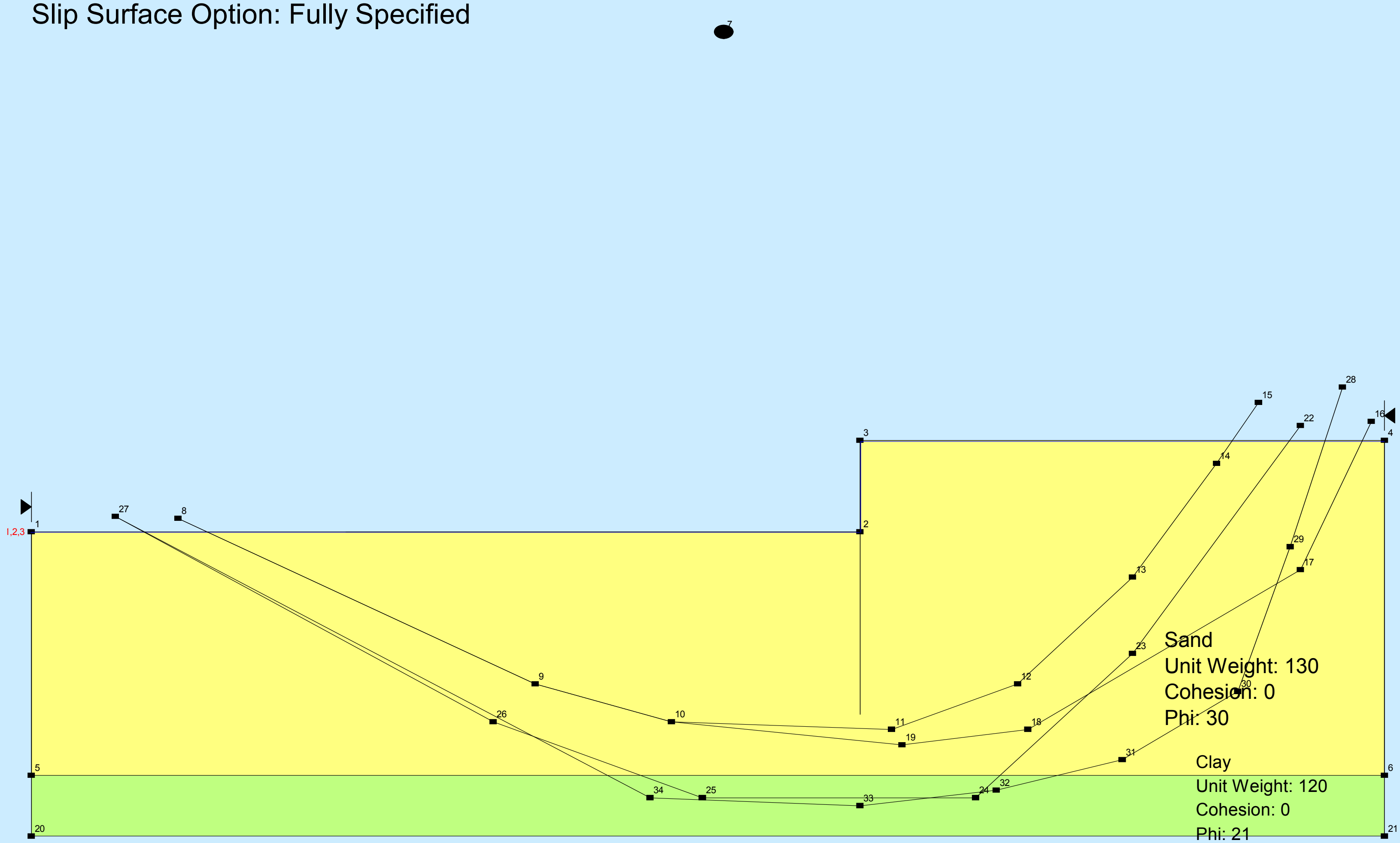


DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

Seabrook Harbor
Slope Stability Analysis
Analysis Method: Bishop (with Ordinary & Janbu)
Slip Surface Option: Fully Specified



- **Component Details**

  - **Waler: 2 x 10” galvanized steel Channels on the outside**
  - **Tiebacks: 18’ long, 2.25” galvanized steel tiebacks with turnbuckle, Oversized to allow for corrosion**
  - **Drains: 2 x 2” dia holes with wire mesh/geotextile backing, located under water to prevent freezing**

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION 227

- Recent Examples Viewed
  - Fiberglass

SECTION 227

- Recent Examples Viewed
  - Vinyl

- **Construction**
  - **October 2004 – April 2005 (within the November-March dredging window)**
  - **Two barges, three cranes, clam shell, dozer, supply boats, Crew of 20**
  - **Hydraulic Dredge**
  - **Hydraulic vibratory hammer**
  - **Design called for vinyl or fiberglass; Contractor Submitted fiberglass sheeting with polyurethane resin (delivery and QC problems resulted in switch to different manufacturer and polyester resin)**
  - **Total length of two bulkheads = 1,700 feet**
  - **Sheet panel length = 27 feet (5 feet cut off to obtain required 22 feet)**
  - **Construction cost = $3 million**

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION 227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

S E C T I O N 227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION 227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

MATERIAL: FRP

WEST BULKHEAD - EAST WALL

DATE DRIVEN	SHEET LOCATION	GROUND ELEV.	TIP ELEV.	SHEET LENGTH	DRIVEN LENGTH	CUTOFF LENGTH	DRIVING TIME H.M.S	VIBRO MODEL	VIBRO WEIGHT	VIBRO FREQUENCY	CUTOFF LENGTH
	1100		-18.5	25'		5	80	216 ICE	5350		
	1097	1.5	-18.5	25'		5	80	216 ICE	5350		
	1094	1.5	-18.5	25'		5	80	216 ICE	5350		
	1091	1.5	-18.5	25'		5	80	216 ICE	5350		
	1088	1.5	-18.5	25'		5	80	216 ICE	5350		
	1085	1.5	-18.5	25'		5	80	216 ICE	5350		
	1082	1.5	-18.5	25'		5	80	216 ICE	5350		
	1079	1.5	-18.5	25'		5	80	216 ICE	5350		
	1076	1.5	-18.5	25'		5	80	216 ICE	5350		
	1073	1.5	-18.5	25'		5	80	216 ICE	5350		
	1070	1.5	-18.5	25'		5	80	216 ICE	5350		
	1067	1.5	-18.5	25'		5	80	216 ICE	5350		
	1064	1.5	-18.5	25'		5	80	216 ICE	5350		
	1061	1.5	-18.5	25'		5	80	216 ICE	5350		
	1058	1.5	-18.5	25'		5	80	216 ICE	5350		
	1055	1.5	-18.5	25'		5	80	216 ICE	5350		
	1052	1.5	-18.5	25'		5	80	216 ICE	5350		
	1049	1.5	-18.5	25'		5	80	216 ICE	5350		
	1046	1.5	-18.5	25'		5	80	216 ICE	5350		
	1043	1.5	-18.5	25'		5	80	216 ICE	5350		
	1040	1.5	-18.5	25'		5	80	216 ICE	5350		
10/28/2004	1037	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1034	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1031	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1028	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1025	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1022	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1019	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1016	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1013	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1010	1.5	-18.5	27		5	80	216 ICE	5350		
10/28/2004	1007	1.5	-18.5	27		5	80	216 ICE	5350		

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION 227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION 227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION 227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION 227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION 227

Field Issues & Lessons Learned

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

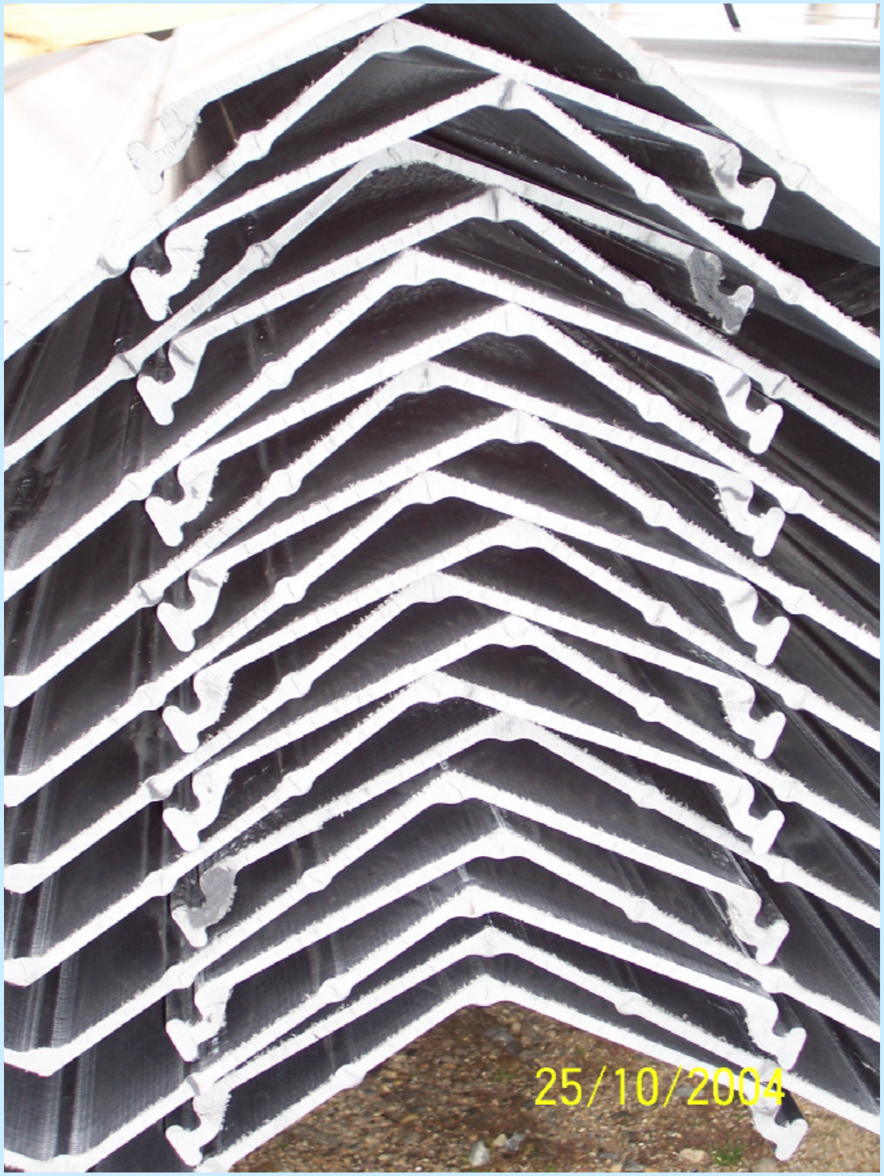
SECTION

227

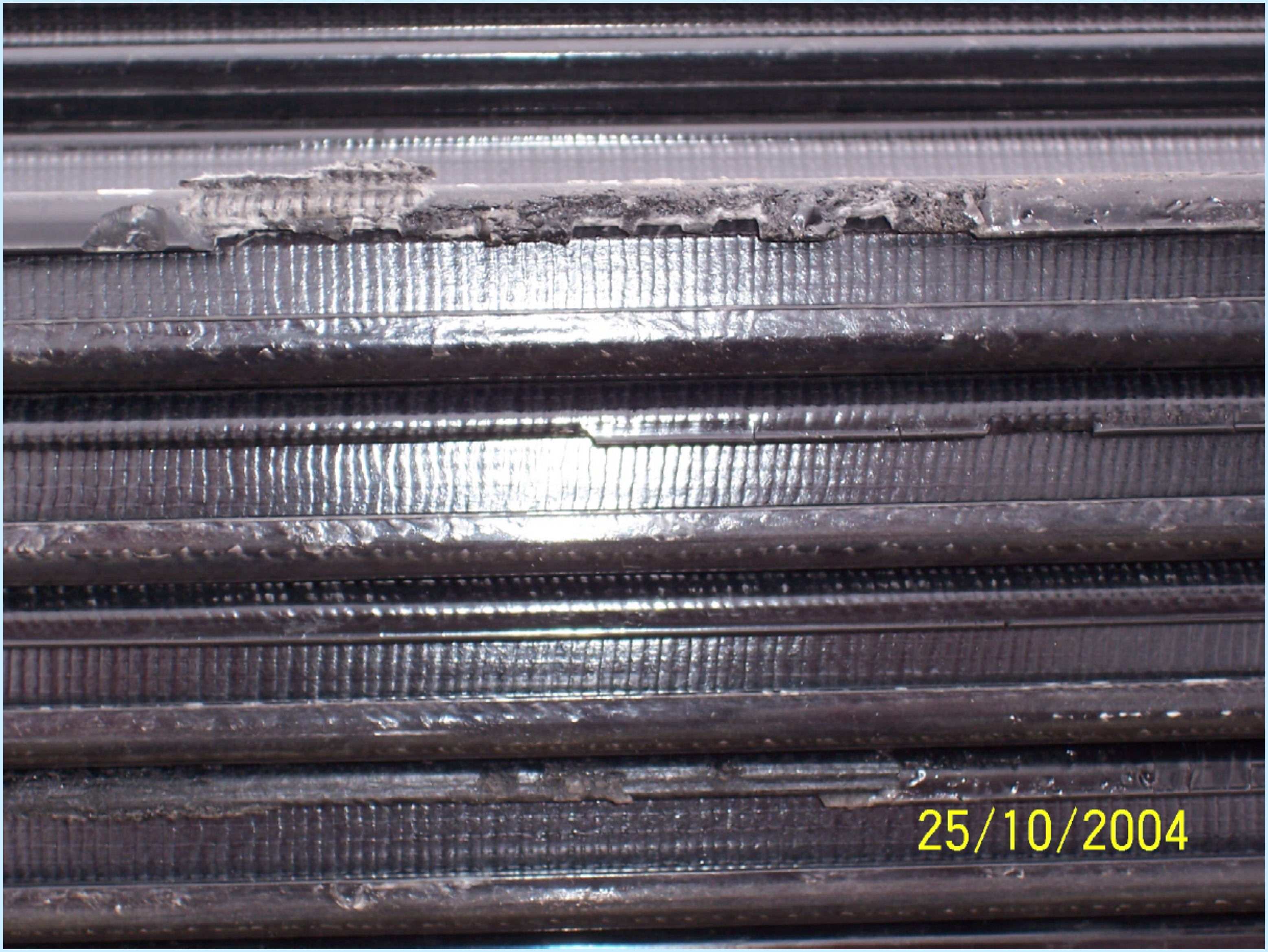
DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227



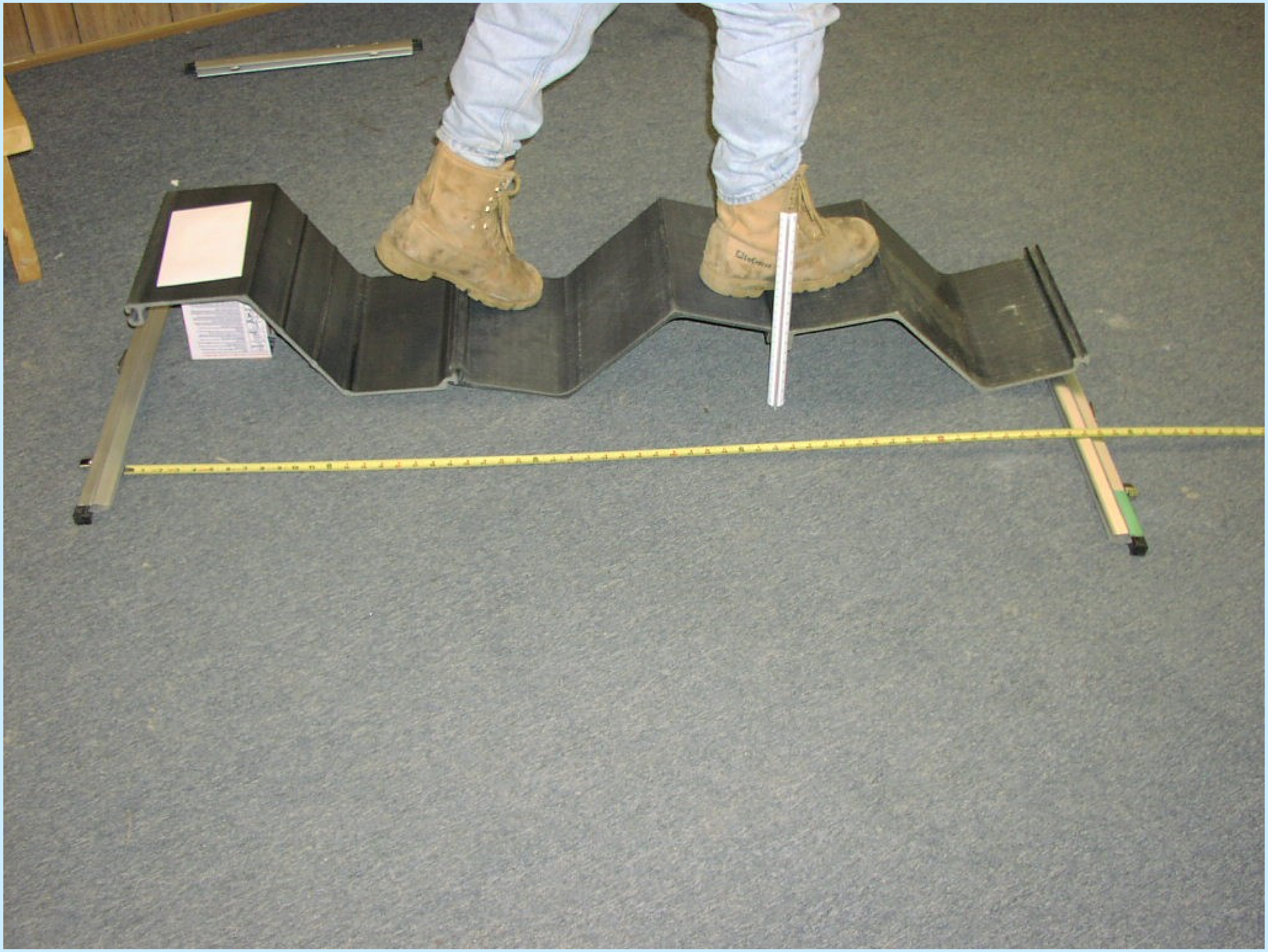
SECTION 227



DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227



DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION 227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

S
E
C
T
I
O
N

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

Instrumentation

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

v

SECTION

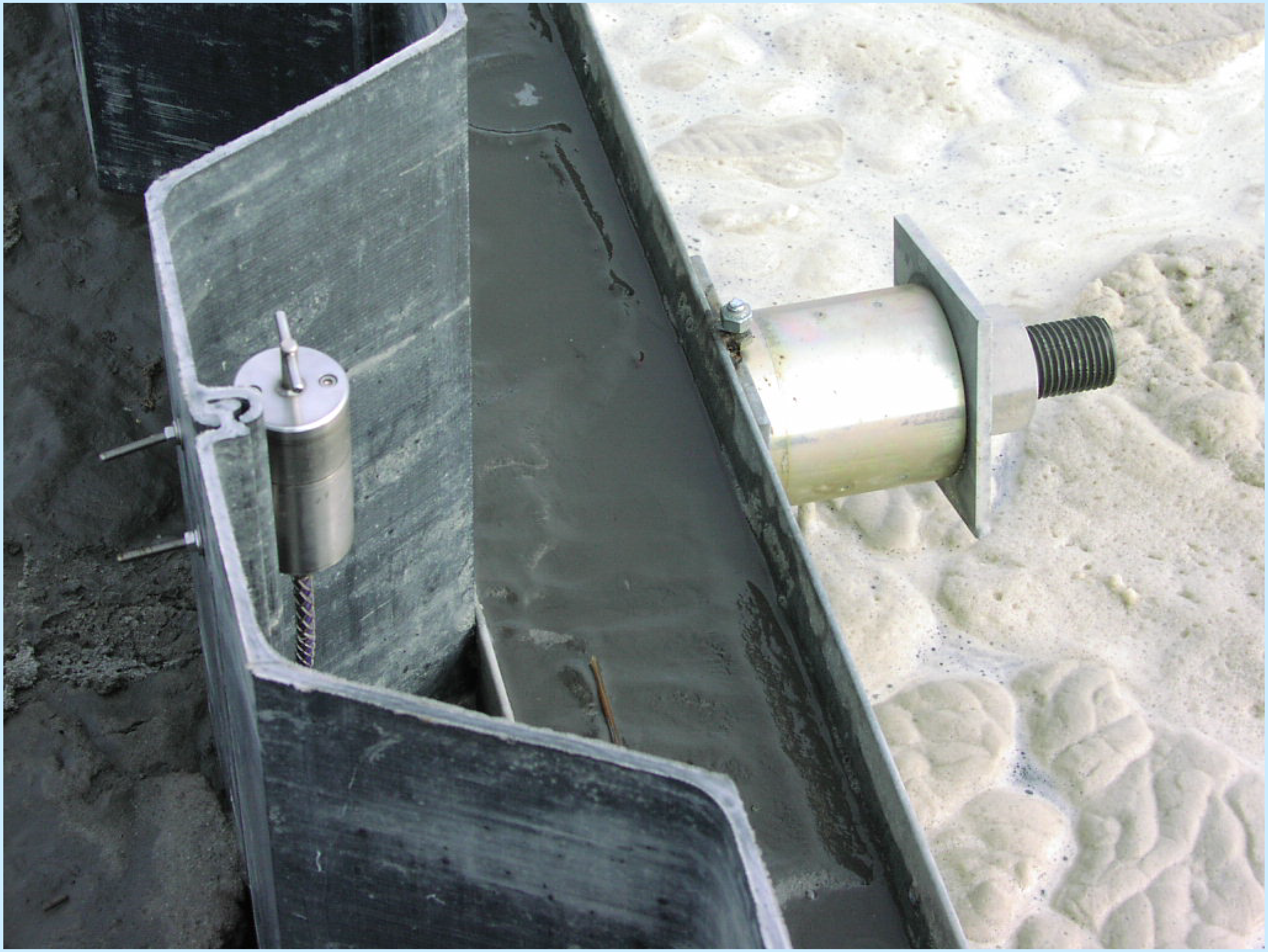
227

Location Station	Date	Time	Well Reading	Well Level MLW	Tide Reading	Tide Level MLW	Delta (Well - Tide)
W4+00…							
1	4/14/05	1049	42"	+1' 11"	36"	+0' 6"	+1' 5"
2	4/15/05	1000	30"	+2' 11"	26.5"	+1' 3.5"	+1' 7.5"
3	4/18/05	1317	34"	+2' 7"	29.5"	+1' 0.5"	+1' 6.5"
4A	4/19/05	1335	29.5"	+2' 11.5"	24.5"	+1' 5.5"	+1' 6"
4B	4/19/05	1440	36.5"	+2' 4.5"	31.5"	+0' 10.5"	+1' 6"
5	4/20/05	1451	33"	+2' 8"	31.5"	+0' 10.5"	+1' 10.5"
6	4/25/05	0659	38.5"	+2' 3"	40.5"	+0' 1.5"	+2' 1.5"

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227



DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

SECTION 227

Deformation Monitoring Log

Project:	Seabrook Harbor Section 227 Project	Date:	4/6/2005
Contract No.:	W912WJ-04-C-0009	Time:	2:30 PM
		Temp:	58°F BP 30.24
		Weather:	FAIR
		Surveyed By:	W. Saucier

Reading Number	Location	Direct Angle	Inverse Angle	Average Angle	Direct Distance	Inverse Distance	Average Distance	Elevation	Deformation From Initial Reading
1	1+38 E	39°39'35"	39°39'39"	39°39'37"	88.24	88.245	88.24	1.77	E 0.069/N 0.00
2	1+38 E	39°39'36"	39°39'42"	39°39'39"	88.235	88.24	88.24	1.77	E 0.068/N 0.00
3	1+38 E	39°39'39"	39°39'41"	39°39'40"	88.245	88.235	88.24	1.77	E 0.068/N 0.00
								0.02	
					Change from initial (inches)				0.83
1	1+60 E	39°34'54"	39°35'00"	39°34'57"	110.025	110.035	110.03	1.82	E 0.044/N 0.00
2	1+60 E	39°34'55"	39°34'57"	39°34'56"	110.03	110.03	110.03	1.82	E 0.044/N 0.00
3	1+60 E	39°35'00"	39°34'54"	39°34'57"	110.035	110.03	110.03	1.82	E 0.044/N 0.00
								0	

Comments

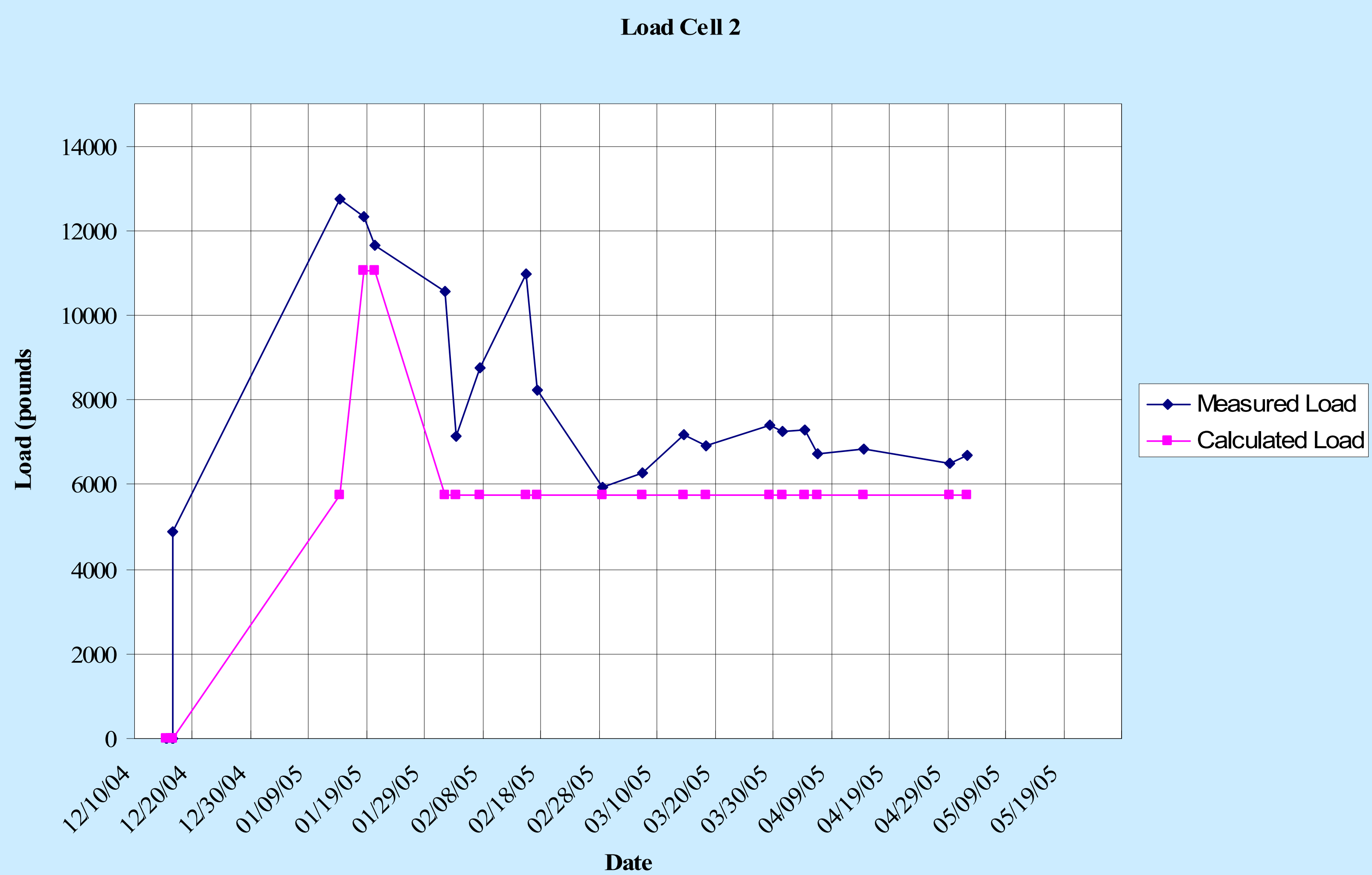
Note:Initial Readings (1+38E 39°42'19" - 88.24 / 1+60E 39°36'19" - 110.03)

Third reading on completed wall

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227



- **Conclusions**
  - **Pick the right application. Despite some manufacturers' claims, steel it is not!**
  - **Synthetic sheeting can be very cost effective (50% of cost of steel is possible)**
  - **Conservatism in design is recommended because of scarcity of test data.**
  - **Construction sequence is crucial to avoid overstressing the material**
  - **Synthetic sheeting is here to stay**

- **Current Needs**
  - **Standard (full scale panel) test methods & corresponding data**
  - **Standard guide specifications**
  - **Long term performance data (longevity)**
  - **Greater number of quality manufacturers**
  - **Information exchange among designers (USACE, NAVY, Others)**
  - **A committee to facilitate the exchange and develop standards**

& our final product….

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES, SEABROOK, NEW HAMPSHIRE

SECTION

227

October 2004

April 2005

S
E
C
T
I
O
N

227

DESIGN AND CONSTRUCTION OF ANCHORED BULKHEADS WITH SYNTHETIC SHEET PILES SEABROOK, NEW HAMPSHIRE

Thank you

siamac.vaghar@usace.army.mil