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NORTH CAROLINA PROFESSIONAL SEAL 15684 ENGINEER BRUCE JAMES MAREK
2-2-2020
Bruce Marek
Pages 1-10

Mr. Stephen Boyett
Village of Bald Head Island Building Inspector
P.O. Box 3009
Bald Head Island, NC 28461

Re: Middle Island POA Cape Creek Marina Floating Docks As-Built Structural Assessment

This letter is submitted in response to a request by Mr Alan Reynor of the Middle Island Property Owners Association, Inc. (MIPOA), in regards to the structural adequacy of their as-built two year old Cape Creek Marina docks (at the end of Cape Creek Road). Particularly with reference to the 13 PTSYP Timber Guide Piles.

The pre-fabricated docks, were built by Bellingham Marine Timber Dock Division, Castle Hayne, NC. Bellingham Timber is the successor company of Sound Marine, who built the majority of the Bald Head Island Marina, Deep Point Marina and Indigo Marina floating docks. I am including a copy of Bellingham's layout drawing(s).

The marina engineering was provided by Jeff Troutman, P.E. of CTT Consulting Engineers, now the Ardura Group. Seal date for the final engineering drawings is 3/6/18. Drawings were prepared in accordance with the 2012 NC Building Code (NCBC), as the effective date for the 2018 Code was not until January 1, 2019. I am also including e-mail correspondence from Mr. Troutman dated 9-5-19, in which he gave me approval to review his drawings and assumptions for this analysis. His plans were based on approved CAMA Permit 8-19.

The Design Criteria is listed on Sheet S0.0. Design Maximum Wind Speed is for 140 mph Unoccupied (i.e. no boats), and 72 mph Occupied (with boats). Design Wave and Water Criteria are for 1.5' significant wave height for the Occupied Condition, with Current Velocity 2 FPS (feet per second) Estimated. For the Unoccupied Condition, wave height is 3.0'.

Mr. Troutman also has a requirement for vessel impact at a 10 degree angle off of centerline for the dock ends, at a vessel impacting speed of 0.5 FPS. NCBC Chapter 36 specifically indicates to use 1.25 x the Kinetic Energy of the impacting vessel. Referenced ASCE 50 recommends using L^2 * 12 as a vessel weight estimation. Using the largest boat = 30', the weight = 30^2*12 =10,800 lbs. K.E.= W*V^2/2*g; thus = 1.25*10800*0.5^2/(2*32.2) = 53 lb-ft.

Estimating a flat bow impact length over the 4' finger pier end, the impact load is 13.25 lbs; over the 5' finger pier end is 10.6 lbs, both very minimal. If we conservatively say the impact is more of a point load, over a 2" length, because bows aren't really sharp and the docks have vinyl fendering, then the point load = 318 lbs. Multiplying by 0.985 (the Cosine of 10 degrees) = 0.985 = P =314 lbs. The finger dock frames consist of double 2x10 ptsyp "Whalers", assumed as #2, with an NDS 2012 allowable bending strength Fb of 1500 psi x 0.85 wet service factor = Fb'=1275 psi. Bending Moment M for a point load is PL/4. To keep consistent with units, the 5' finger dock has a width of 60". The larger M from boat impact = 314 x 60/4 = 4710 inch-lbs. Section Modulus S for the Double 2x10's = bh^2/6 = (3x9.25^2)/6= 42.8 inches^3. Stress = M/S = 4710/42.8 = 110 psi, which is much less than Fb' = 1275 psi. Note that all of the finger dock end centers are "protected" by the piles and steel pipe hoops,

Ignoring the additional strength of the 4x4 "Torsion Beam" backing the mechanically laminated "Whalers", if we assume that the 4x6 (nominal) "Cross Beams" have a spacing of 72" a 10 degree impact would be 314 x 72/4 = 5652 inch-lbs /42.8 in^3 = 132 psi. If hit at a splice, then 264 psi.

Back-calculating, if hit at a splice joint (i.e. only one 2x10 "active") and if there were no 4x6 Cross Beams, the Whalers are good for a length of 29'. Thus, the as-built finger docks are structurally sufficient for vessel impact.

In order to perform my as- built analysis, I did site visits on 8-29-19 and 10-18-19. The 8-29-19 visit, with you, was at or very near to low tide, and rising. I measured 19" from the top of the docks to the water, i.e. dock freeboard. This meets deadload freeboard standards. ASCE Manual 50, a Troutman referenced document, "Planning and Design Guidelines for Small Craft Harbors, ASCE Manuals and Reports on Engineering Practice No 50", Third Edition, 2012, indicates private pedestrian marinas to be designed to 30 psf Live Load. Per Section 36 of the 2012 NCBC, floating docks are to be designed for a 20 psf Live Load. Jeff Troutman had called out 40 psf Live Load on Sheet S0.0, but I understand that he agreed to Bellingham's 30 psf standard use for the purchased series of docks.

The Dead Load Only submerged float portion is appx 6 ½". I rounded up to 0.6' for my calculations. There is a total of 6'x108'+2x4'x24'+2x4'x22'+5'x35' = 1191 sf of floating dock. 30 psf x 1191 sf = 35730 lbs. Dividing by 185 lbs AWPP (Average Weight Per Person) = 193 persons. The 30 psf Live load sinkage would be approximately to the underside of the 9.25" 2x10 Whalers, which is about 0.8' of live load sinkage. I Don't think there are that many people on Middle Island, let alone to be on the dock all at once for 9 boats. Again, this meets industry standards for floating docks, keeping the "Whalers" at or above the water at full Live Load.

As I have done on several occasions elsewhere on the island, I called to the BHI Harbor Master to get a simultaneous measurement of distance down to the water at the Bald Head Island Marina Bulkhead Cap. On that day/time, it was 87" = 7.25'.

The Bald Head Island Marina Cap elevation is app 4.92 FMSL NAVD 88. (It was built as 6.0 FMSL in 1983-1984 using then in effect NGVD27). Using the Monthly Daily Tide Charts for the year, there is a maximum tide range of 6.3'. For drawing purposes, MLLW is at -2.4' FMSL and MHHW is +3.9' FMSL, or about 1' below the marina cap. Which is about right, as the Ferry Terminal Gate A Landing is 1' below the cap, and a few times a year (king tides, or with several days of south or southeast winds, we get water over the A Landing. The Contractor "B" Gate Landing is level with the bulkhead cap, so does not get affected. In 20 years, I have only seen or heard of only about 3 or 4 documented over toppings of the bulkhead.

Using the above values, I calculated the approximate top of guide pile elevation as 13' FMSL. This is 8' above the Bald Head Island Marina Cap, and is probably on the tall side of the Bald Head Island Marina floating dock guide piles, which are in the 6' to 8' range above the bulkhead cap. Neither the NCBC 2012 or ASCE 50 have specific pile height requirements. Mr. Troutman, for bid purposes, indicated 45' pile lengths for both the 5 waterward and 8 landward piles. He also indicated a top of pile height of +18 FMSL, or 13' above the BHI Marina bulkhead cap. There would be serious problems with the entire island if the water ever got that high. In the e-mail submittal for Building Permit, Middle Island POA indicated the selection of 35' pile length for the waterward piles and 30' for the landward piles, (my understanding per POA vote based on cost estimates and available budget).

Mr. Troutman's Cover Sheet S0.0 indicates a design wind speed of 72 mph Occupied (with boats) and 140 mph Unoccupied (i.e. no boats). Design wave and water criteria are for 1.5' significant wave height for the Occupied Condition, with current velocity 2 FPS (feet per second). For the Unoccupied 140 mph Condition, design wave height is 3.0'.

These seemingly simple design criteria actually lead to numerous sheets of design calculation, as I needed to evaluate with wind and waves either parallel or perpendicular to the main (6'x108') dock, current from any direction, and at MLLW and at MHW. For this report, I am only submitting the believed highest two load cases: the Occupied Condition which is for the Waterward Piles, Perpendicular Wind and Current, at Low Tide; and for the Unoccupied Condition, the Landward Piles, Perpendicular Wind and Waves at Low Tide.

Mil-HDBK 1025/5, as Referenced by ASCE 50, gives a worked wind example with calculations separately for wind parallel and perpendicular to the main dock, (see pages 28, 32 & 33). Shielding at 20% of load (0.20) is utilized for other than "first row". The Figure 15 Sample Calculation for Wind Loading on a Floating Pier System looks quite simple when only calculating wind load on the boats, i.e. occupied marina. ASCE 50 details the same shielding approach for wind and water.

Sheet S0.0 references **ASTM D25-12 (Reapproved 2017)** "Standard Specification for Round Timber Piles". Table X1.3 is the relevant page/table for pile sizing for Southern Yellow Pine Timber Piles, giving pile Butt Circumferences and Diameters for pile length groupings, and their corresponding minimum tip circumference and diameter, as timber piles have a taper to them. Butt diameters are measured at three foot from the top (= fat) end. While structurally a butt end down pile would theoretically have better pull out resistance, in practicality driving the small end down is easier to install and to more precisely position. Marina Guide Piles are almost always driven tip down. ASTM D25 further references **ASTM D2555-17a Standard Practice for Establishing Clear Wood Values**; and **ASTM D2899 Standard Practice for Establishing Allowable Stresses for Round Timber Piles.**

For timber pile and embedment analysis, I also utilized **FEMA P-55, the Coastal Construction Manual**, and its companion CCM Calculator; **"Self-Supported Wood Poles Fixity at ANSI Groundline"** by Mehran Keshavarzian, P.E.; **ASCE Manual of Practice 141 "Wood Pole Structures for Electrical Transmission Lines", 2019; ANSI O5.1-2017 Wood Poles: Specifications and Dimensions**; the **"Timber Pile Design and Construction Manal"** published by the Timber Pile Council; **"Foundation Analysis and Design"**, by Joseph Bowles, P.E.; and **"Advanced Foundation Engineering"** by V.N.S. Murthy, 2007. The latter four utilize Broms Method(s) for the Analysis of Laterally Loaded Piles, based on his papers published in 1964.

As excerpted from Advanced Foundation Engineering, "his (Broms) theory deals with the following: 1. Lateral deflections of piles at ground level at working loads. 2. Ultimate soil resistance of soil. He has considered short and long piles embedded in both cohesive (clayey) and cohesionless (granular) soils." Broms theory is considered under the following headings: 1. Lateral deflections at working loads in saturated cohesive soils (1964a). 2. Ultimate lateral resistance of piles in cohesive soils (1964a). 3. Lateral Deflections at working loads in cohesionless soils (1964b). 4. Ultimate lateral resistance of piles in cohesionless soils (1964b).

Topics 3 & 4 are appropriate for the Cape Creek Marina piles. First thing is to calculate, and to understand, the embedment designations of Long Pile, Short Pile and Intermediate Pile. Short Pile embedment is such that a soil failure is predicted. I.e. the pile can tip over. Just like the recent example of the border wall in California. Long Pile embedment is such that there will be a limited amount of soil deflection at the groundline interface. In such cases, the piles will lean (static) or work back and forth (cyclic loading). Guidelines are for recommended design static deflection in the range of 0.5" to 1.5" at groundline, with cyclic loading said to be double the static deflection. There are no limits indicated on pile movement (groundline deflection) on sheet S0.0, which is the typical case for timber guide pile marinas. You can go up and push on a pile, and it will move. This greatly reduces the stress on a pile. However, pile movement also makes it more difficult to calculate.

Note that NCBC 2012 Chapter 36 is silent on pile deflection, pile height and pile embedment. We do know that sand is somewhat self-healing, as fines and silt can redeposit over time and help lessen pile movement. With Long Pile Embedment, it is possible for a pile to break. However, with calculatable movement at the groundline (or mudline, as often used for piles that are installed below water), and the inherent flexibility of a timber pile, the piles are only quasi-rigid members. the breakage to me is less likely to occur with when analyzing based on ultimate strength of the piles, as ultimate strength of the soil is used to calculate groundline deflection, rather than NDS (National Design Specification for Wood Construction) allowable strength. In wood, the ultimate strength is called the MOR, the Modulus of Rupture. NDS allowable strengths Fb has a 4 or higher Factor of Safety.

Step 1 Determine the General Soil Type (i.e. cohesive (clayey) or cohesionless (granular)) within the critical depth below the ground surface (appx 4 to 5 pile diameters)
From a Typical Bald Head Island Soil Report, taken across the road from the Island Hardware Store, grade elevation appx 5.0 FMSL NAVD88, beneath the surface to a depth of 52' (-47 FMSL) the test borings typically encountered intermittent a layer of very loose to dense clean sand (SP). From 52' to 57' (-52 FMSL) test borings encountered a layer of stiff sandy clay (CL). From 57' to 90' (-85 FMSL), the test borings typically encountered a layer of medium dense to very dense clayey sand (SC). Standard Test Penetrations (SPT) N values in the first 57' were 4 to 32 blows per ft (bpf). At the elevation of our pile embedments, the avg N of six borings is appx 20. This is consistent with over 20 years of soil observations on Bald Head Island and at the nearby creeks. Thus use the Cohesionless Soil Formulas.

From TDCM Table 5.1 Empirical Correlation for Effective Friction Angle, After Bowles	Loose Sand	Medium Sand	Dense Sand	Very Dense Sand
Corrected N	4 to 10	10 to 30	30 to 50	50+
phi angle	27 to 32 degr	30-35 degr	35 to 40 degr	38-43 degr
For Design Calculations, This Project: assumed angle of internal friction phi		32.5	37.5 Degr	

Step 2 Determine the coefficient of horizontal subgrade reaction, Kh, within the critical depth for cohesive soils.
From Pile Driver Tommy Perry Conversations, the Middle Island Marina Area has a dense sand bottom, as evidenced by breaking cable(s) in pulling out the old piles.
Table 7.2 Values of Kh (kcf) for Cohesionless Soils: Loose Density Abv Groundwater Kh = 12, Below Kh = 7, Medium abv Groundwater Kh=52, Blw = 35, Dense Abv = 112, Below = 69
Assume Medium Dense Below Groundwater (estimate (35+69)/2) = 52 (from TPUSCM Table 7.2)
Unconfined compressive strength for Cohesive Soils Kh = n1*n2*1670*qu/b. Therefore qu psf = Kh*1000*Pile Diam b/(n1*n2*1670), n1 = 0.32 for qu < 1 ksf, 0.36 for 1 to 4, n2 = 1.3 for timber

	Waterward Piles As Built	Waterward Piles As Designed	Landward Piles As Built	Landward Piles As Designed
Med Density Sand SP phi=32.5 deg				
Pile Length	35.00 ft	45.00 ft	30.00 ft	45.00 ft
Embedded Length D	7.40 ft	12.40 ft	9.90 ft	10.50 ft
Appx Pile Diameter D at Mudline based on ASTM D25 Table X1.3 Taper	8.4"	10.5"	7.0"	11.5"
	0.72 ft	0.88 ft	0.58 ft	0.96 ft
Pile Area at Mudline	55.4 in^2	83.2 in^2	38.5 in^2	103.9 in^2
Moment of Inertia I = pi...	244.4 in^4	615.2 in^4	117.9 in^4	858.5 in^4
Modulus of Elasticity for Southern Pine Piles: Avg ANSI, NDS & ABS: E = 1.9 x 10^6 psi	EI = 464 x 10^6 lb-in^2	EI = 1117 x 10^6 lb-in^2	EI = 224 x 10^6 lb-in^2	EI = 1631 x 10^6 lb-in^2
Table 7.2 Medium Dense Sand, Below Groundwater, Kh = 52 kcf	52 kcf	52 kcf	52 kcf	52 kcf
Step 3 Determine n for cohesionless soils = (Kh/EI)^1/5 ANSI O5.1 E1	0.640	0.538	0.747	0.502
nD	4.26	6.68	7.40	5.39
Determine if the pile is long nD>4, short nD<2, or intermediate (btwn 2 and 4)	long	long	long	long
Max Embedded Length D for nD <= 2 = Short Pile = Typ Failure in Soil	Short Pile <= 3.10 ft Embedment	Short Pile <= 3.73 ft Embedment	Short Pile <= 2.68 ft Embedment	Short Pile <= 3.98 ft Embedment
Min Embedded Length D for nD >= 4 = Long Pile	Long Pile >= 6.19 ft Embedment	Long Pile >= 7.46 ft Embedment	Long Pile >= 5.35 ft Embedment	Long Pile >= 7.97 ft Embedment

ASCE 141 "Wood Pole Structures for Electrical Transmission Lines" and **ANSI O5.1-2017 Wood Poles: Specifications and Dimensions** give relevant guidance on the MOR values and Modulus of Elasticity E., ANSI O5.1 indicates in Table 1, Group D, for Southern Pine Poles a MOR of 8000 psi and Modulus of Elasticity E as 2.13 x 10^6 psi. **ABS (American Bureau of Shipping)** "ABS YACHTS 2018, Part 3 Chapter 2 Section 3 Table 10 Properties of Various Woods" lists Southern Pine MOR as 14,500 psi with E = 1.98 x 10^6 psi. NDS does not indicate MOR, but for design Modulus of Elasticity of 1.5 x 10^6 psi. For Calculations, I use an average of the 3 Modulus of Elasticity E = 1.9 x 10^6 psi = 1900 ksi.

From the above calculations, you can see that the As-Built and the Troutman Bid 45' Piles all meet the Long Pile embedment criteria of nD >=4. Also per the calcs, you can see that the larger diameter = stiffer 45' Length 14" butt diameter ASTM D25 taper Southern Pine piles embedded with their tops at elevation +18 FMSL, require an additional appx 1.5' of embedment to meet the 4.0 Long Pile criteria.

INITIAL CONSIDERATIONS 19

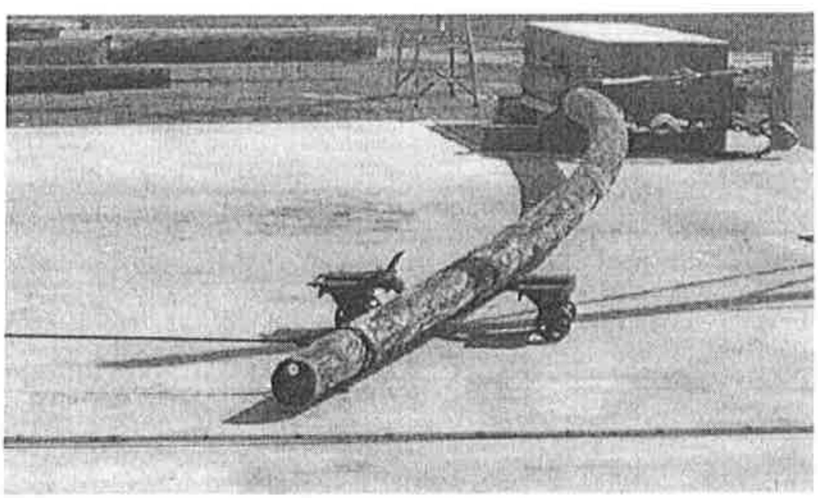
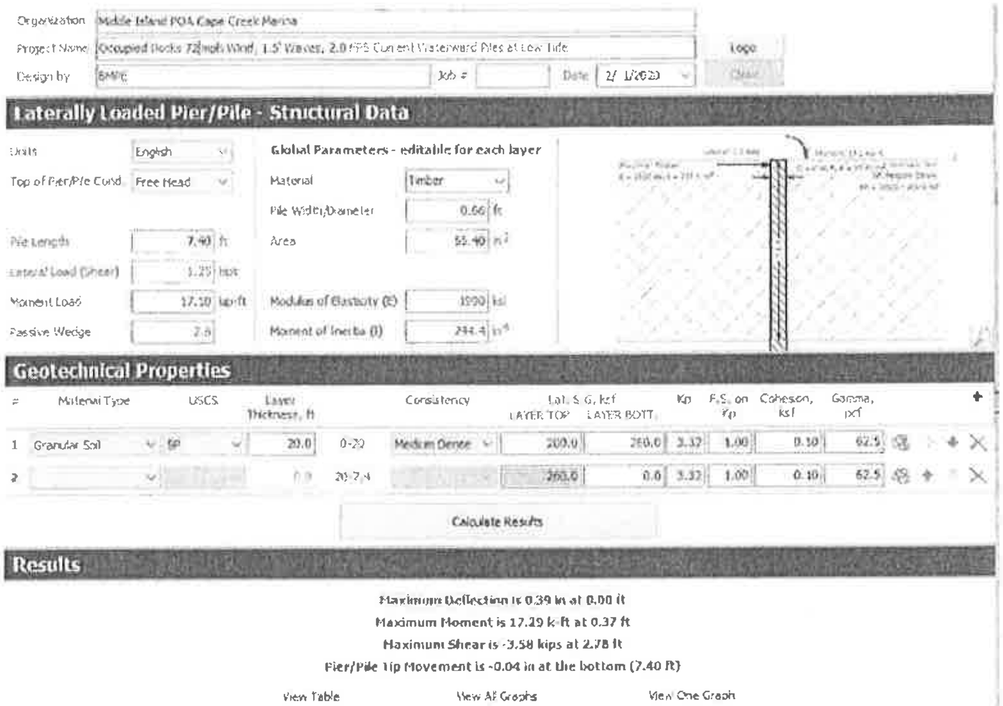
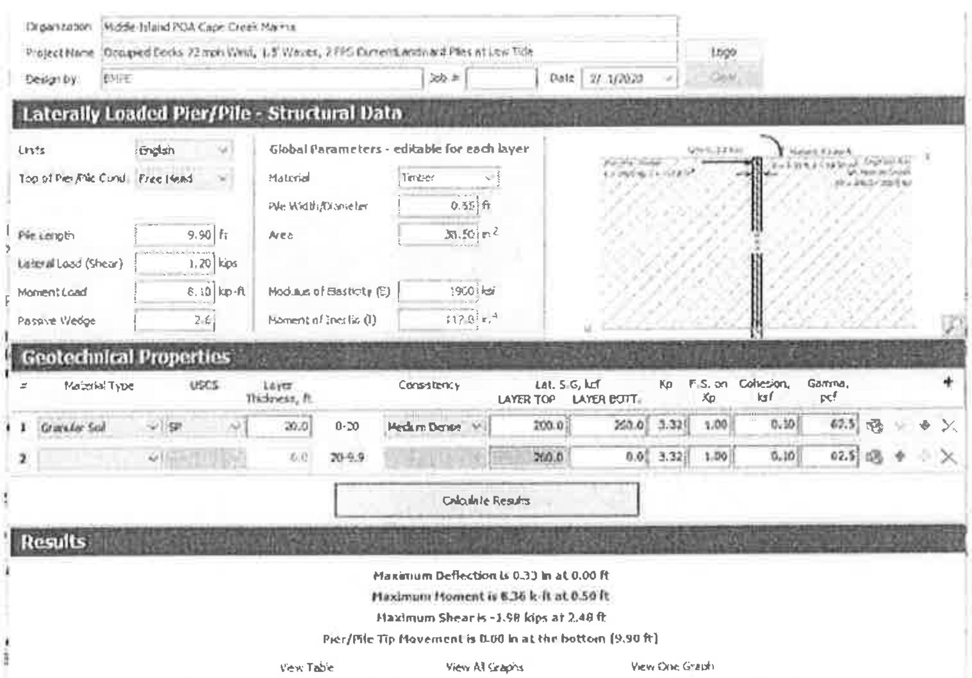


Figure 2-6. Single pole load and deflection test.
Source: Osmose Utilities Services, Inc., reprinted with permission.

We rarely see utility poles or marina piles bent this much, but poles/piles can take a lot of bend.

There are no limits indicated on pile movement based on sheet S0.0. This is the typical for timber guide pile marinas. You can go up and push on a pile, and it will move. This greatly reduces the stress on a pile. However, pile movement also makes it more difficult to calculate. The NC 2012 Chapter 36 is silent on pile deflection, pile height and pile embedment. See the below calculations for mudline deflection.





Organization: Middle Island POA Cape Creek Marina

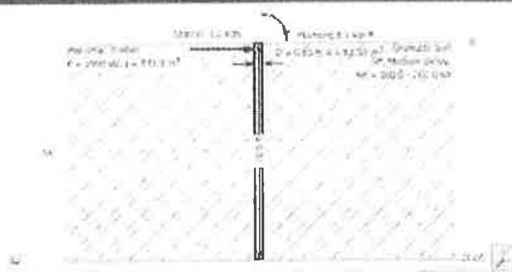
Project Name: Occupied Docks 72 mph Wind, 1.5' Waves, 2 FPS Current. Landward Piles at Low Tide 45' Piles

Design by: BMPE | Job #: | Date: 2/ 1/2020

Logo

Laterally Loaded Pier/Pile - Structural Data

Units	English	**Global Parameters - editable for each layer**	
Top of Pier/Pile Cond.	Free Head	Material	Timber
		Pile Width/Diameter	0.85 ft
Pile Length	19.90 ft	Area	82.50 in²
Lateral Load (Shear)	1.20 kips		
Moment Load	8.10 kip-ft	Modulus of Elasticity (E)	1900 ksi
Passive Wedge	2.6	Moment of Inertia (I)	541.5 in⁴



Geotechnical Properties

#	Material Type	USCS	Layer Thickness, ft		Consistency	Lat. S.G, kcf LAYER TOP	Lat. S.G, kcf LAYER BOTT.	Kp	F.S. on Kp	Cohesion, ksf	Gamma, pcf
1	Granular Soil	SP	20.0	0-20	Medium Dense	200.0	260.0	3.32	1.00	0.10	62.5
2			0.0	20-19.9		260.0	0.0	3.32	1.00	0.10	62.5

Calculate Results

Results

Maximum Deflection is 0.14 in at 0.00 ft

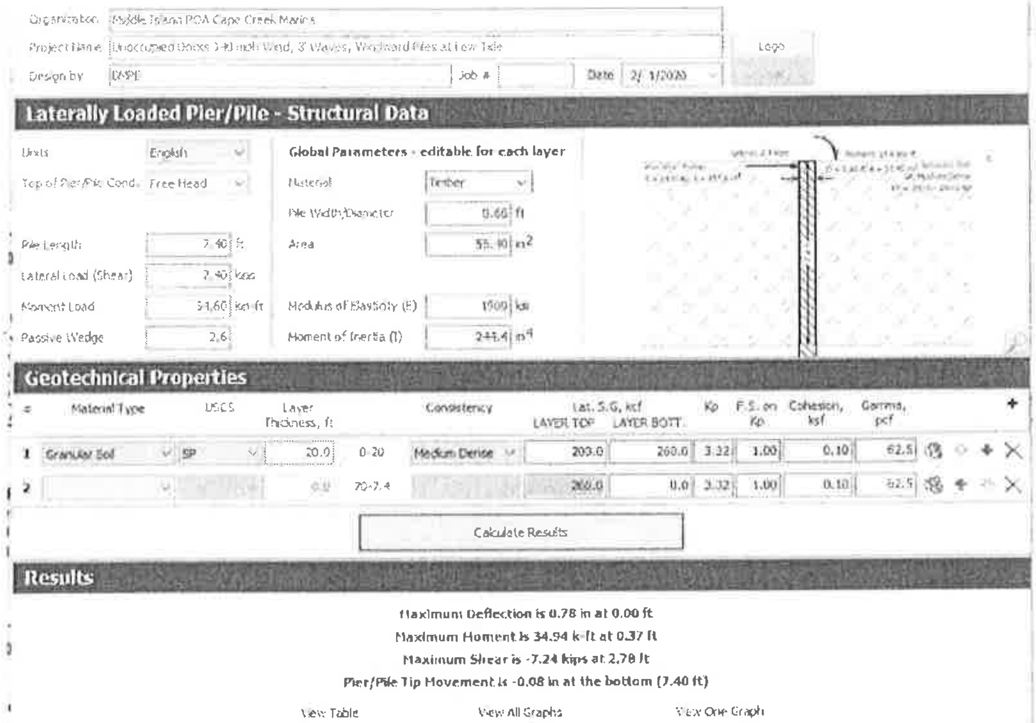
Maximum Moment is 8.48 k-ft at 1.00 ft

Maximum Shear is -1.54 kips at 3.48 ft

Pier/Pile Tip Movement is 0.00 in at the bottom (19.90 ft)

View Table | View All Graphs | View One Graph

For the With Boats, 72 mph (Category 1 Hurricane) load case, with 1.5' waves and 2 FPS current, the calculated deflection for the as built piles at mudline is 0.39" for the waterward and 0.33" for the landward piles. If the landward piles were 45' in length 14" diameter at 3' from the end, the deflection at mudline drops to 0.14". For cyclic loading, references indicate that the deflection values should be doubled. So, we are talking about in a Cat 1 Hurricane ¾" of predicted deflection as-built, and 5/16" with 45' piles without adding the extra wind lateral load and moment due to the 5' taller pile height. So maybe 3/8" of predicted pile movement difference.



Organization: Middle Island POA Cape Creek Marina
Project Name: Unoccupied Docks 140 mph Wind, 3' Waves, Windward Piles at Low Tide
Design by: BMPE | Job #: | Date: 2/ 1/2020 | Logo

Laterally Loaded Pier/Pile - Structural Data

Units: English
Top of Pier/Pile Cond.: Free Head
Pile Length: 7.40 ft
Lateral Load (Shear): 2.40 kips
Moment Load: 34.60 kip-ft
Passive Wedge: 2.6

Global Parameters - editable for each layer
Material: Timber
Pile Width/Diameter: 0.60 ft
Area: 55.40 in^2
Modulus of Elasticity (E): 1900 ksi
Moment of Inertia (I): 244.4 in^4

Geotechnical Properties

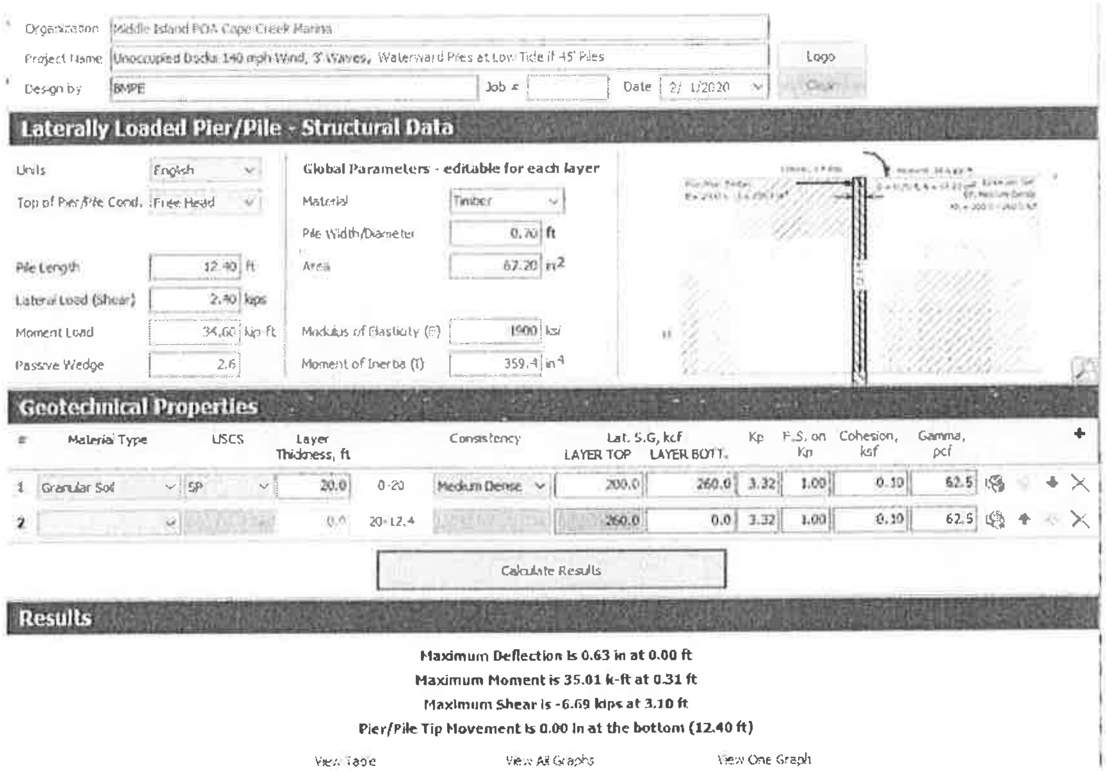
#	Material Type	USCS	Layer Thickness, ft		Consistency	Lat. S.G, kcf LAYER TOP	LAYER BOTT.	Kp	F.S. on Kp	Cohesion, ksf	Gamma, pcf
1	Granular Soil	SP	20.0	0-20	Medium Dense	200.0	260.0	3.32	1.00	0.10	62.5
2			0.0	20-7.4		260.0	0.0	3.32	1.00	0.10	62.5

Calculate Results

Results

Maximum Deflection is 0.78 in at 0.00 ft
Maximum Moment is 34.94 k-ft at 0.37 ft
Maximum Shear is -7.24 kips at 2.78 ft
Pier/Pile Tip Movement is -0.08 in at the bottom (7.40 ft)

View Table | View All Graphs | View One Graph



Organization: Middle Island POA Cape Creek Marina
Project Name: Unoccupied Docks 140 mph Wind, 3' Waves, Waterward Piles at Low Tide if 45' Piles
Design by: BMPE | Job #: | Date: 2/ 1/2020 | Logo | Clear

Laterally Loaded Pier/Pile - Structural Data

Units: English
Top of Pier/Pile Cond.: Free Head
Pile Length: 12.40 ft
Lateral Load (Shear): 2.40 kips
Moment Load: 34.60 kip-ft
Passive Wedge: 2.6

Global Parameters - editable for each layer
Material: Timber
Pile Width/Diameter: 0.70 ft
Area: 67.20 in^2
Modulus of Elasticity (E): 1900 ksi
Moment of Inertia (I): 359.4 in^4

Geotechnical Properties

#	Material Type	USCS	Layer Thickness, ft		Consistency	Lat. S.G, kcf LAYER TOP	LAYER BOTT.	Kp	F.S. on Kp	Cohesion, ksf	Gamma, pcf
1	Granular Soil	SP	20.0	0-20	Medium Dense	200.0	260.0	3.32	1.00	0.10	62.5
2			0.0	20-12.4		260.0	0.0	3.32	1.00	0.10	62.5

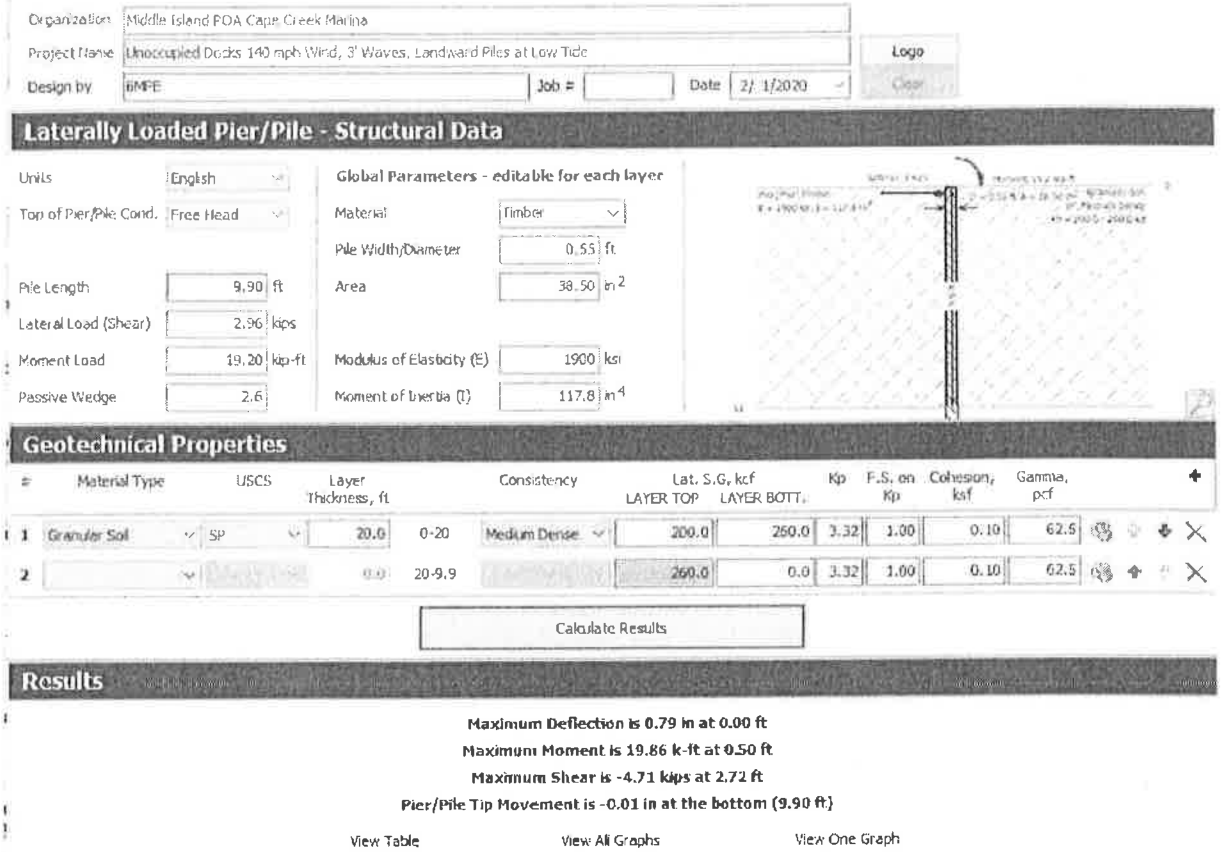
Calculate Results

Results

Maximum Deflection is 0.63 in at 0.00 ft
Maximum Moment is 35.01 k-ft at 0.31 ft
Maximum Shear is -6.69 kips at 3.10 ft
Pier/Pile Tip Movement is 0.00 in at the bottom (12.40 ft)

View Table | View All Graphs | View One Graph

Waterward Piles in 140 mph wind and 3' waves. .78" static deflection for as-built, 0.63" for 45' piles.



Organization: Middle Island POA Cape Creek Marina
Project Name: Unoccupied Docks 140 mph Wind, 3' Waves, Landward Piles at Low Tide
Design by: BMPE | Job #: | Date: 2/ 1/2020 | Logo | Clear

Laterally Loaded Pier/Pile - Structural Data

Units	English	**Global Parameters - editable for each layer**	
Top of Pier/Pile Cond.	Free Head	Material	Timber
		Pile Width/Diameter	0.55 ft
Pile Length	9.90 ft	Area	38.50 in²
Lateral Load (Shear)	2.96 kips		
Moment Load	19.20 kip-ft	Modulus of Elasticity (E)	1900 ksi
Passive Wedge	2.6	Moment of Inertia (I)	117.8 in⁴

Geotechnical Properties

#	Material Type	USCS	Layer Thickness, ft		Consistency	Lat. S.G. kcf LAYER TOP	LAYER BOTT.	Kp	F.S. on Kp	Cohesion, ksf	Gamma, pcf
1	Granular Soil	SP	20.0	0-20	Medium Dense	200.0	260.0	3.32	1.00	0.10	62.5
2			0.0	20-9.9		260.0	0.0	3.32	1.00	0.10	62.5

Calculate Results

Results

Maximum Deflection is 0.79 in at 0.00 ft
Maximum Moment is 19.86 k-ft at 0.50 ft
Maximum Shear is -4.71 kips at 2.72 ft
Pier/Pile Tip Movement is -0.01 in at the bottom (9.90 ft)

View Table | View All Graphs | View One Graph

Note that the Landward as-built pile 30' timber pile mudline static deflection is predicted at 0.79" deflection and the Waterward as-built 35' piles is predicted at 0.78" static load deflection, so the 35' waterward and 30' landward matchup has pretty even calculated deflection, and both are under 1" static mudline deflection. Again, it would be correct to at least double that amount for cyclic loading of wind and waves, and duration could mean more. But as a comparative analysis, the mudline deflections for both the as-built and the bid sized piles are within reasonable structural limits. (Nothing says though that after a hurricane that piles might not need some aesthetic straightening and resetting. And marina piles should be checked yearly for worms, borers, and signs of decay.)

In my load cases analysis, the low tide condition had higher lateral load than the high tide condition. For simplicity, the above software printouts which show both lateral load and moment load, were only run for the load tide case. I have also run with dense sandy soil which indicates less deflection, but I am sure that reams of paper do not change the overall trend shown in the above six printouts.

Based on proprietary soil reports on Bald Head Island that I have been privy to, the initial sand layer goes to an elevation depth of appx -50 FMSL of Soil Classification SP (Poorly Graded Sand), and thence a 5-10' band of Clayey Sand (CS), and thence dense to very dense sandy clay (SC). My assumption is that the piles are entirely in the SP soil classification.

Typically, in Brunswick and New Hanover Counties, marina timber piles are driven to refusal, which in the Southport/Bald Head Island area is in the 6' to 10'-12' depth of embedment range. Trying to go deeper can cause the piles to split. I have locally even seen concrete piles specified to deeper depths crack when tried to be over-driven past refusal.

As a point of reference, at the Bald Head Island Club, the (new) pool restaurant (Horizons) piles, which were specified to a 16' embedment, had to be auger drilled inside of a steel casing (hollow steel pipe, I think 18" or 24" in diameter), and then backfilled once the pile was inserted, set and backfilled, in order to achieve the 16' pile embedment of the 10"x10" (and I think some 12"x12") building piles. A specialized firm was employed to reach those depths, at much cost.

Please note that the pile software calculates a maximum moment location which is in the 3" to 12" range below the mudline. If these were piles rigidly embedded into concrete (a fixed cantilever beam condition) maximum moment would be at the top of the concrete. I point this out to show that accommodation is taken for this groundline movement. I do not include a further reduction for scour, as the loss of soil rigidity would be similar whether the as-built or the bid piles. As the creek flow can change based on upstream or downstream shape changes due to siltation and/or erosion, with or without hurricane force storms, it goes to the "see something/say something mantra, that the marina users should notify the POA representatives if they observe changes at the marina or by relative pile push movement.

The final segment of analysis is the strength of the piles. My program runs used the average pile diameter below the mudline, but for pile strength I use the actual pile avg diameter at mudline. (i.e. that version of the software doesn't account for timber pile taper). The area and moment of inertia I inputted above, however, are for the actual mudline diameter. For pile strength I use the same loads and moments as in the software runs, but convert to lbs and inch-lbs rather than kips and kip-ft. Note: Section Modulus S = (pi*b^3)/32: Shear Stress fv = 4V/3A; Bending Stress fb = M/S

Waterward Piles with Boats: Lateral Load (Shear) at mudline = 1250 lbs; Calculated Max Shear below grade = 3,580 lbs; Calculated Max Moment = 17.29 kip-ft = 207,480 inch lbs, mudline diameter b= 8.4", Section Modulus S = 58.2 in^3, Nominal Shear Area A =55.4 in^2. Thus fv at mudline = 30 psi. fv max = 86 psi. Bending stress fb = 3565 psi.

Landward Piles with Boats: Lateral Load (Shear) at mudline = 1200 lbs; Calculated Max Shear below grade = 1980 lbs; Calculated Max Moment = 8.36 kip-ft = 100,320 inch lbs, mudline diameter b= 7", Section Modulus S = 33.7 in^3, Nominal Shear Area A =38.5 in^2. Thus fv at mudline = 42 psi. fv max = 69 psi. Bending stress fb = 2977 psi.

For the Occupied Slips Condition with 72 mph wind, 1.5' waves and 2 FPS current, the pile shear stresses are all beneath the NDS 2012 Table 6A allowable shear stress Fv= 160 psi, even at max shear below groundline. Waterward Pile Bending Stress has a Factor of Safety of 2.25 based on ANSI O5.1 MOR 8000 psi. Landward Pile Bending Stress has a Factor of Safety of 2.68.

Waterward Piles without Boats: Lateral Load (Shear) at mudline = 2400 lbs; Calculated Max Shear below grade = 7240 lbs; Calculated Max Moment = 34.94 kip-ft = 419,280 inch lbs, mudline diameter b= 8.4", Section Modulus S = 58.2 in^3, Nominal Shear Area A =55.4 in^2. Thus fv at mudline = 58 psi. fv max = 174 psi. Bending stress fb = 7204 psi.

Landward Piles without Boats: Lateral Load (Shear) at mudline = ~~2960~~ 2600 lbs; Calculated Max Shear below grade = ~~4710~~ 4350 lbs; Calculated Max Moment = ~~19.86~~ 17.2 kip-ft = ~~238,320~~ 206,400 inch lbs, mudline diameter b= 7", Section Modulus S = 33.7 in^3, Nominal Shear Area A =38.5 in^2. Thus fv at mudline = ~~103~~ 90 psi. fv max = ~~163~~ 150 psi. Bending stress fb = ~~7071~~ 6125 psi.

For the Unoccupied Slips Condition with 140 mph wind, 3' wave, the pile shear stresses are beneath the NDS 2012 Table 6A allowable shear stress Fv= 160 psi except for the max shear below groundline on the waterward piles of 174 psi = 9% over; unfactored values are a bit more difficult to find, but my boat books have various values of 640 psi to 1040 psi for vertical shear: 174 psi Waterward falls well below ultimate values. Waterward Pile Bending Stress has a Factor of Safety of 1.11 based on ANSI O5.1 MOR 8000 psi. Landward Pile Bending Stress has a Factor of Safety of 1.30. Note that for Timber Utility Poles in extreme wind conditions, a F.S of 1.0 is considered structurally sufficient.

The timber guide piles have relatively no axial down load to them other than self-weight, and would only be expected to have axial upload during an extreme storm only if the dock height floats to above the appx 12.75 FMSL pin height to the14 FMSL VE zone, that could possible raise the dock about 15", but not enough to pull the piles out of the mudline.

Wood piles do require checking, as worms, checks, etc can degrade the structural integrity. Likewise, creek scour and/or currents can change the bottom profile, even when not storm related. A jut out/sand build up on one side of the creek can greatly affect the depths along the creek as the waterflow adjusts direction.

Additionally, I have looked at the fixed pier structure at the top of the dock ramp, and while the decking looks in good shape, the piles are starting to show their age. As you are aware, NC DEQ CAMA issues repair exemptions for pile repair/replacement and dock repairs. Deck board replacement now no longer needs permission.

This certification of marina structural as-built sufficiency should not be taken as not needing owner provided maintenance.

Please note that NFPA 303 Marinas would require fire extinguishers at a maximum spacing of 75'. I.e. one near the base of the ramp and then one 75' max away along the 6' wide main dock.

Certification:
I find that the Bellingham Marine Timber Division Wood Docks and the Middle Island HOA procured 30' and 35' timber piles have structural sufficiency for the designated design lateral shear loads and moments from wind, water, waves, current with boats for a Category 1 (72 mph) Hurricane, for a 140 mph Extreme Wind & Waves Event without boats, and for vertical dock loads as indicated, based on my August and October 2019 site visits and subsequent engineering calculations.

NORTH CAROLINA PROFESSIONAL SEAL 15684 ENGINEER BRUCE JAMES MAREK

2-2-20

Respectfully,

Bruce Marek, P.E.

Bruce Marek

PAGES 1-10

TABLE X1.3 Specified Butt Circumferences with Corresponding Minimum Tip Circumferences for Southern Yellow Pine Piles[A,B,C,D,E]

Required Minimum Circumference, in. 3 ft from Butts	22 [7]	25 [8]	28 [9]	31 [10]	35 [11]	38 [12]	41 [12]	44 [14]	47 [15]	50 [16]	57 [18]
Length (ft)	Minimum Tip Circumferences, in.										
20	16 [5.1]	16 [5.1]	18 [5.7]	21 [6.7]	25 [8.0]	28 [8.9]	31 [9.9]	34 [10.8]	37 [11.8]	40 [12.7]	47 [15.0]
25	16 [5.1]	16 [5.1]	17 [5.4]	20 [6.4]	24 [7.6]	27 [8.6]	30 [9.5]	33 [10.5]	36 [11.4]	39 [12.4]	46 [14.6]
30	16 [5.1]	16 [5.1]	16 [5.1]	19 [6.0]	23 [7.3]	26 [8.3]	29 [9.2]	32 [10.2]	35 [11.1]	38 [12.1]	45 [14.3]
35	...	...	...	18 [5.7]	22 [7.0]	25 [8.0]	28 [8.9]	31 [9.9]	34 [10.8]	37 [11.8]	44 [14.0]
40	...	...	...	17 [5.4]	21 [6.7]	24 [7.6]	27 [8.6]	30 [9.5]	33 [10.5]	36 [11.4]	43 [13.7]
45	...	...	...	...	20 [6.4]	23 [7.3]	26 [8.3]	29 [9.2]	32 [10.2]	35 [11.1]	42 [13.4]
50	...	...	...	...	19 [6.0]	22 [7.0]	25 [8.0]	28 [8.9]	31 [9.9]	34 [10.8]	41 [13.0]
55	...	...	...	...	...	21 [6.7]	24 [7.6]	27 [8.6]	30 [9.5]	33 [10.5]	40 [12.7]
60	...	...	...	...	...	20 [6.4]	23 [7.3]	26 [8.3]	29 [9.2]	32 [10.2]	39 [12.4]
65	...	...	...	...	...	19 [6.0]	22 [7.0]	25 [8.0]	28 [8.9]	31 [9.9]	38 [12.1]
70	...	...	...	...	...	18 [5.7]	21 [6.7]	24 [7.6]	27 [8.6]	30 [9.5]	37 [11.8]
75	...	...	...	...	...	...	20 [6.4]	23 [7.3]	26 [8.3]	29 [9.2]	36 [11.4]
80	...	...	...	...	...	...	19 [6.0]	22 [7.0]	25 [8.0]	28 [8.9]	35 [11.1]
85	...	...	...	...	...	...	18 [5.7]	21 [6.7]	24 [7.6]	27 [8.6]	34 [10.8]

[A] Where the taper applied to the butt circumferences calculate to a circumference at the tip of less than 16 in., the individual values have been increased to 16 in. to ensure a minimum of 5-in. tip for purposes of driving.

[B] To convert to metric dimensions, 1 in. = 25.4 mm.

[C] Class A piles are all those listed with a specified required minimum circumference of 44 in. at 3 ft from butt.

[D] Class B piles are those listed with a specified required minimum circumference at 3 ft from butt of 35 in. and lengths of 20 to 25 ft minimum circumference at 3 ft from butt of 38 in. and lengths of 20 to 50 ft, and minimum circumference at 3 ft from butt of 41 in. and lengths of 55 to 60 ft.

[E] Southern Yellow Pine piles are generally available in lengths shorter than 70 ft or girth of less than 50 in. at 3 ft from butt. A dark horizontal line in each column designates pile sizes (above the line) which are generally available. The purchaser should inquire as to availability of sizes below the lines.

BRUCE MAREK, P.E.
5489 Eastwind Rd
Wilmington, NC 28403
marekyd@ec.rr.com
Feb 2, 2020

With over thirty years of licensed professional engineering experience, Bruce Marek is a Life Member of the American Society of Civil Engineers. Bruce is licensed in 10 states plus Washington, DC. Bruce has over twenty years of project engineering on Bald Head Island, including: CAMA and Stormwater Permitting, Marina and Bulkhead Engineering, Site Design and Infrastructure Engineering. He also designed the Bald Head Island 82' Aluminum Catamaran Ferries Patriot and Ranger. Dock engineering projects include National Harbor Marina, Prince George's County, MD and M.I.T.'s dinghy docks.

1976 – University of Notre Dame - B.S. Civil Engineering
1990 - Graduate Level Foundations Engineering Course, NC State University Distance Learning. This class was in conjunction with the Wilmington Army Corps of Engineers and was taught by Professor Joseph Bowles, P.E., author of "Foundation Analysis and Design", an industry standard.
1996 – Graduate Level Composites Engineering Course, NC State University Distance Learning

Professional Engineer – Civil Engineering (1988)
Professional Engineer – Naval Architecture (1999)
Professional Engineer – Structural I Engineering (1998)
Professional Engineer – Mechanical Engineering (2006)

Affiliations:
American Society of Civil Engineers, Life Member 2018
Society of Naval Architects and Marine Engineers
American Welding Society
United States Sailing Association

Wood Specific Engineering:
2002 AFPA National Design Specifications for Wood Construction Canvas Committee Member
1996-1999 Product Technical Engineer for Louisiana-Pacific's Engineered Wood Facility on Hway 421, Wilmington, NC (Wood I-Joists and Laminated Veer Beams (LVL))

marekyd@ec.rr.com

From: Jeffrey Troutman <jtroutman@ardurra.com>
Sent: Tuesday, September 3, 2019 4:31 PM
To: marekyd@ec.rr.com
Subject: RE: Middle Island Marina Dock

Bruce,

Per our phone discussion this afternoon, you have my permission to perform a review of my floating dock drawings and specifically for the timber guide piles. Thanks for your assistance.

Thanks,
Jeff

Jeffrey R Troutman, PE, SECB, M. ASCE
Ardurra Group North Carolina
Technical Director
Sr. Project Manager/Structural Engineer

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jtroutman@ardurra.com
O: 910.397.2929
M: 910.297.4049
3809 Peachtree Avenue, Suite 102
Wilmington, NC 28403
www.ardurra.com

From: marekyd@ec.rr.com <marekyd@ec.rr.com>
Sent: Tuesday, September 03, 2019 4:21 PM
To: Jeffrey Troutman <jtroutman@ardurra.com>
Cc: marekyd@ec.rr.com
Subject: FW: Middle Island Marina Dock

Missed the first "r".

From: marekyd@ec.rr.com <marekyd@ec.rr.com>
Sent: Tuesday, September 3, 2019 4:18 PM
To: jtroutman@adurra.com
Cc: marekyd@ec.rr.com
Subject: Middle Island Marina Dock

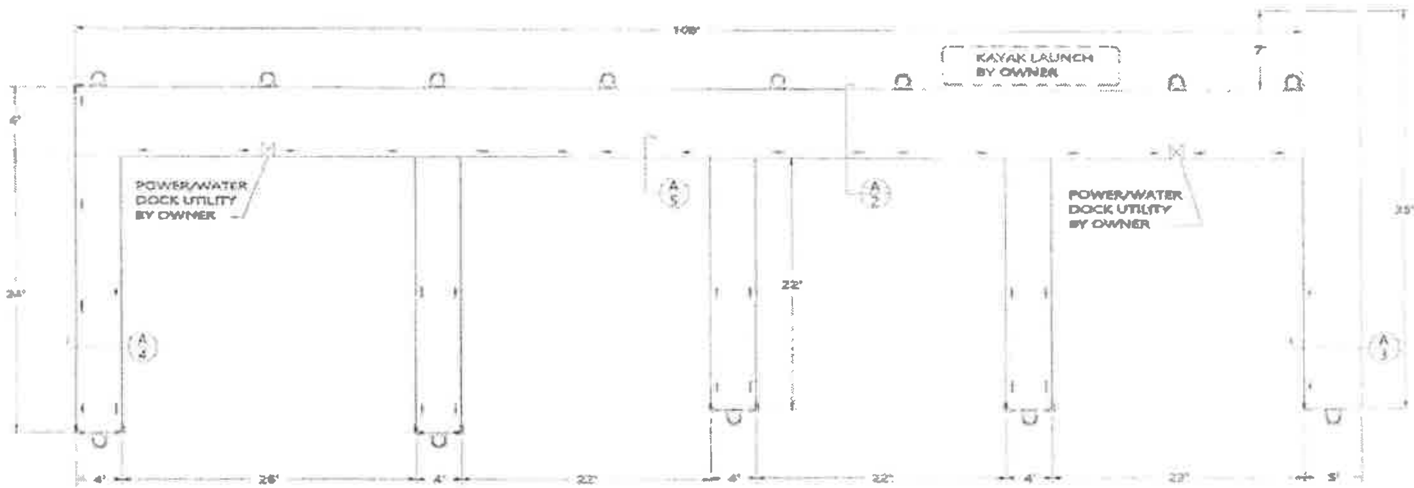
Hi Jeff,

It was a pleasure talking to you today. As I mentioned, I have been asked by a member of the Middle Island Homeowner's Association to take a look at their marina dock piles. Before doing any appropriate calculations, I wanted to inform you that I have been asked to look at your drawings to evaluate the as-built sufficiency of the piles. As I understand it, your drawings specified, for bid purposes, 45' marine treated timber piles. Due to budget constraints, shorter piles were purchased and installed. I probably won't get to calculations until after Hurricane Dorian comes through the area later this week, and probably will do another site visit to verify conditions.

Bruce

Bruce Marek, P.E.
5489 Eastwind Rd.
Wilmington, NC 28403
910-799-9245
Cell 910-228-2484

APPROVED NO EXCEPTION TAKEN
APPROVED AS NOTED
REVISE AN RESUBMIT
REJECTED
SUBMIT SPECIFIED ITEM
By ______ Date 5-29-18



OVERALL DOCK LAYOUT

PILE RETAINER LOCATIONS AND QUANTITIES SHOWN FOR ESTIMATING PURPOSES ONLY.
BELLINGHAM MARINE HAS NOT PERFORMED ANY PILE DESIGN ENGINEERING SERVICES.
BELLINGHAM MARINE RECOMMENDS RETAINING A PROFESSIONAL ENGINEER TO PROVIDE ANCHOR PILE DESIGN SERVICES PRIOR TO CONSTRUCTION.

Bellingham
MARINE
The World's Most Comprehensive Marine Builder

Timber Division

MIDDLE ISLAND HOA

BALD HEAD ISLAND
NORTH CAROLINA

PROPOSED DOCK

JOB # 8282

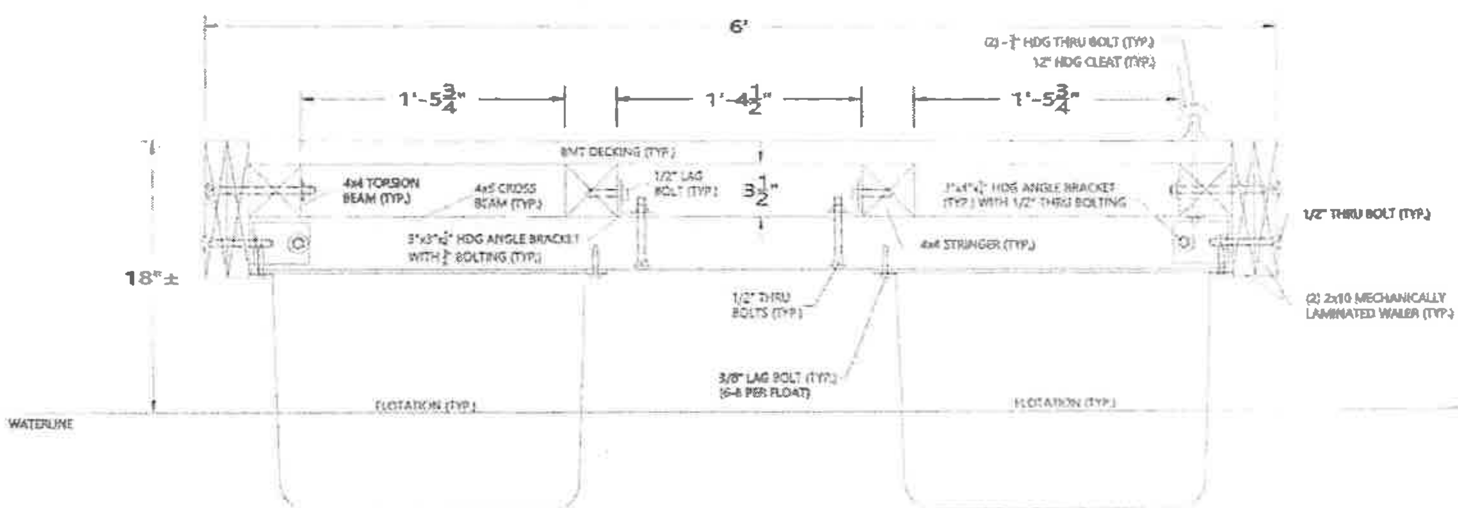
Checked By: ______ Date: ______

Revision: MAY 29, 2018

Drawn by: B.P.R.
Scale: Not To Scale
Date: MAY 21, 2018
NM#: ML-1600000
Sheet: 1 Of 6

NOTES

LEGEND



6' CROSS SECTION (A/2)

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- [ ] APPROVED AS NOTED
- [ ] REVISE AN RESUBMIT
- [ ] REJECTED
- [ ] SUBMIT SPECIFIED ITEM

By [signature] Date 5-29-18

Bellingham MARINE
The World's Most Comprehensive Marine Builder

Timber Division

MIDDLE ISLAND HOA

BALD HEAD ISLAND
NORTH CAROLINA

6' SECTION

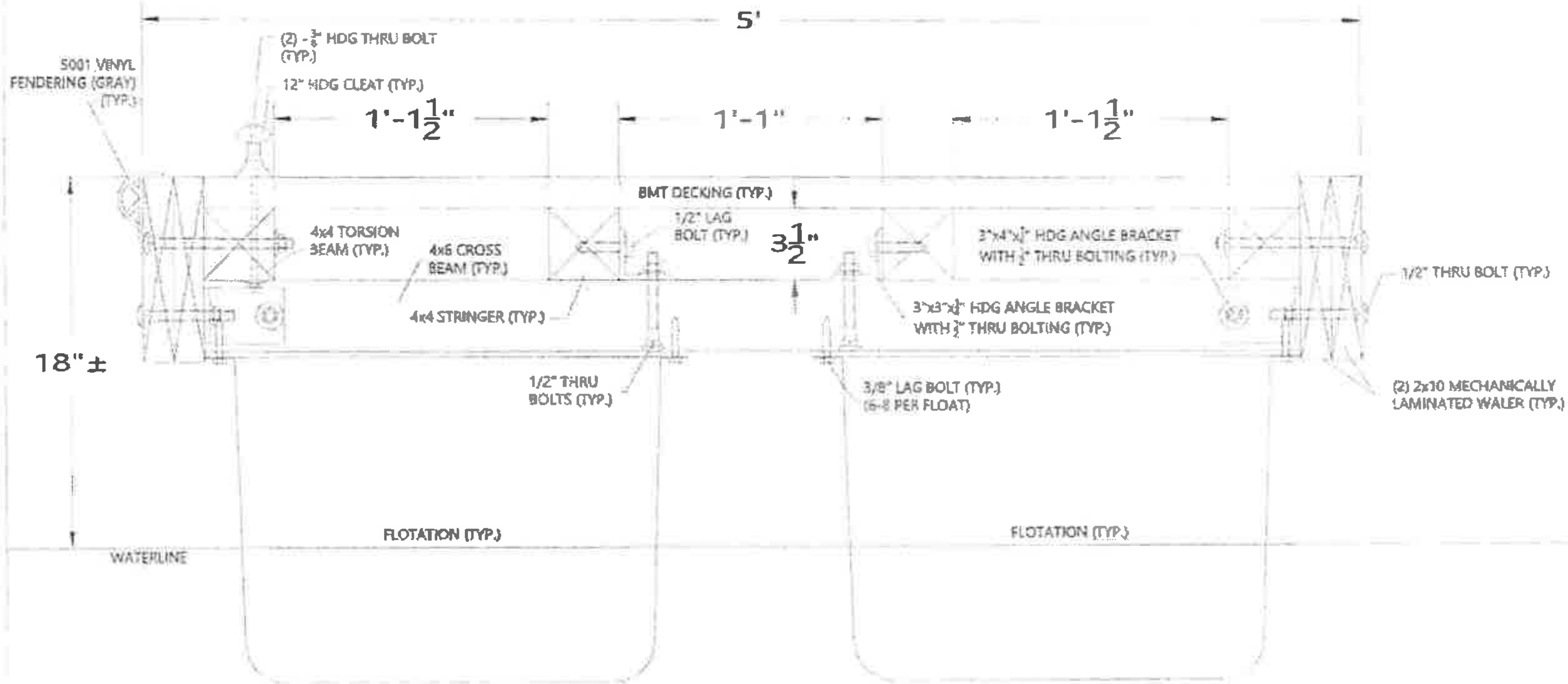
JOB # 8282

Checked By: ____ Date: ____

Revision:

Drawn by: B.P.R.
Scale: Not To Scale
Date: MAY 21, 2018
MH: ML-1600000
Sheet: 2 Of 8

NOTES



5' CROSS SECTION (A/3)

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APPROVED AS NOTED
☐ REVISE AN RESUBMIT
☐ REJECTED
SUBMIT SPECIFIED ITEM
By ______ Date 5-29-18

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MIDDLE ISLAND HOA

BALD HEAD ISLAND
NORTH CAROLINA

5' SECTION

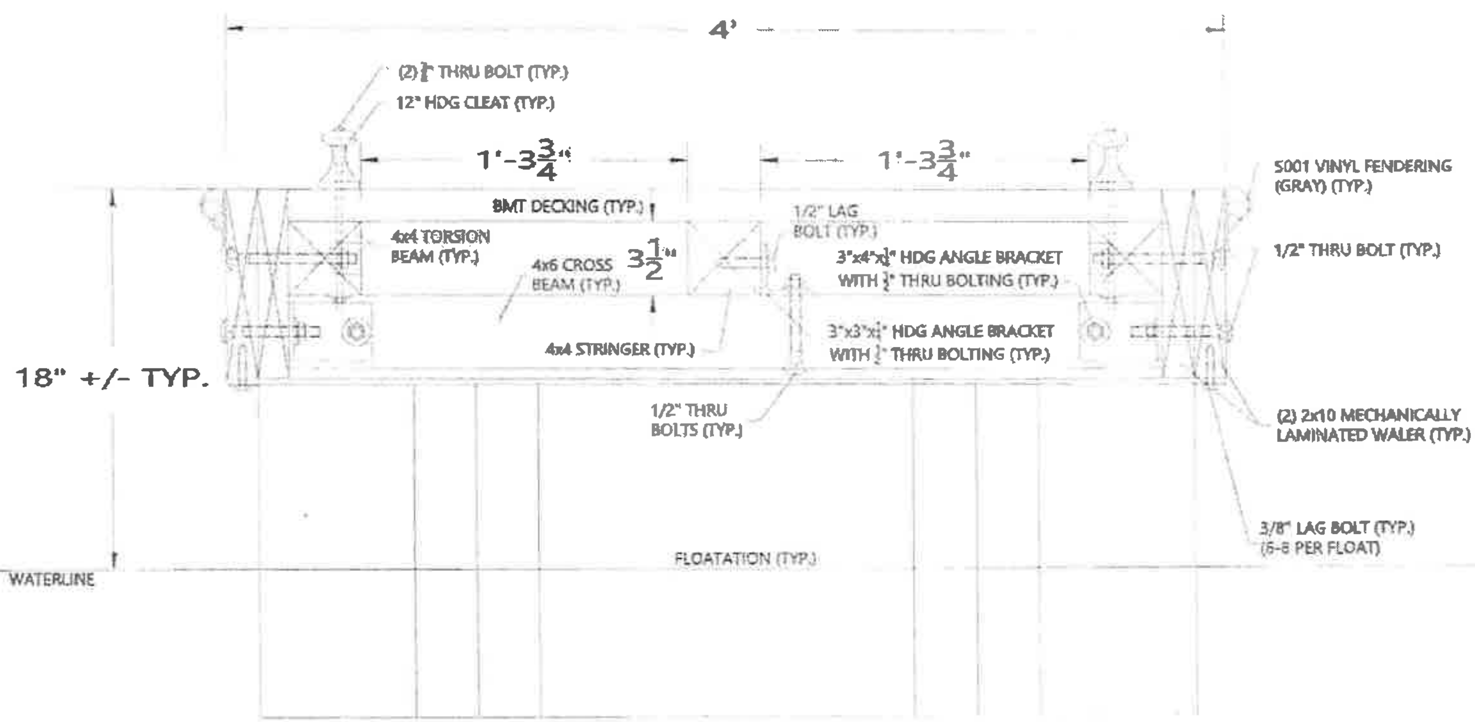
JOB # 8282

Checked By: ______ Date: ______

Revisions:

Drawn by: B.P.R.
Scale: Not To Scale
Date: MAY 21, 2018
MH#: ML-1600000
Sheet: 3 Of 8

NOTES



4' CROSS SECTION (A/4)

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☐ REJECTED
☐ SUBMIT SPECIFIED ITEM
By: [signature] Date: 5-29-18

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MIDDLE ISLAND HOA

BALD HEAD ISLAND
NORTH CAROLINA

4' SECTION

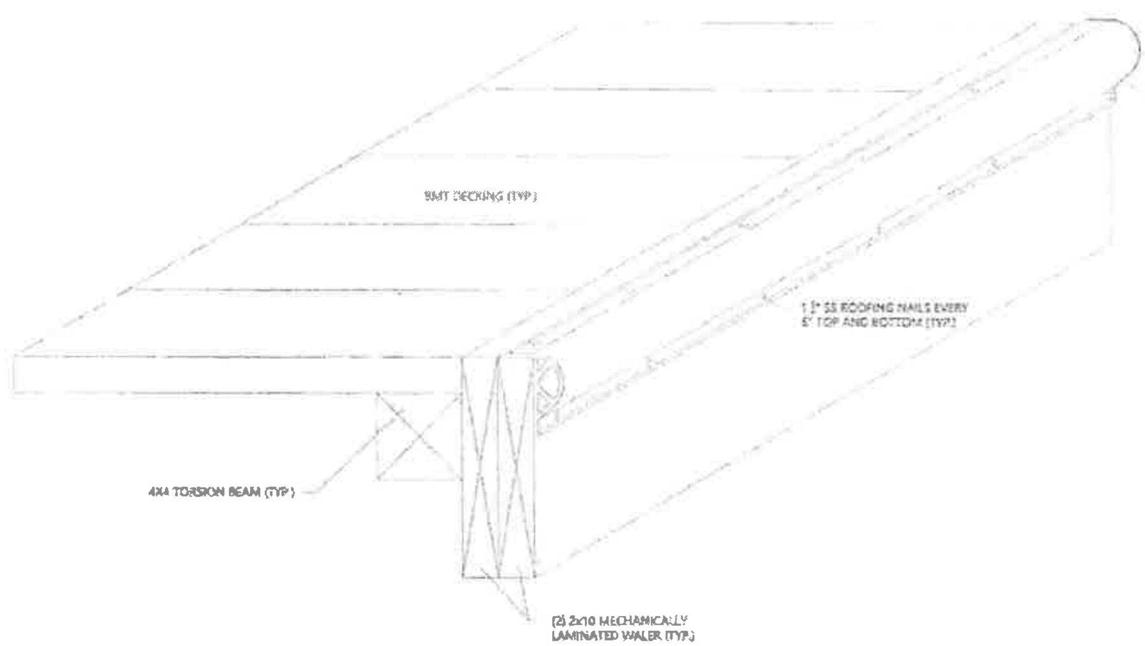
JOB # 8282

Checked By: ______ Date: ______

Revisions:

Drawn by: B.P.R.
Scale: Not To Scale
Date: MAY 21, 2018
MI#: ML-1500000
Sheet: 4 Of 8

NOTES



FENDERING DETAIL

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☐ APPROVED AS NOTED
☐ REVISE AN RESUBMIT
☐ REJECTED
☐ SUBMIT SPECIFIED ITEM

By: [signature] Date: 5-25-18

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MIDDLE ISLAND HOA

BALD HEAD ISLAND
NORTH CAROLINA

FENDERING DETAIL

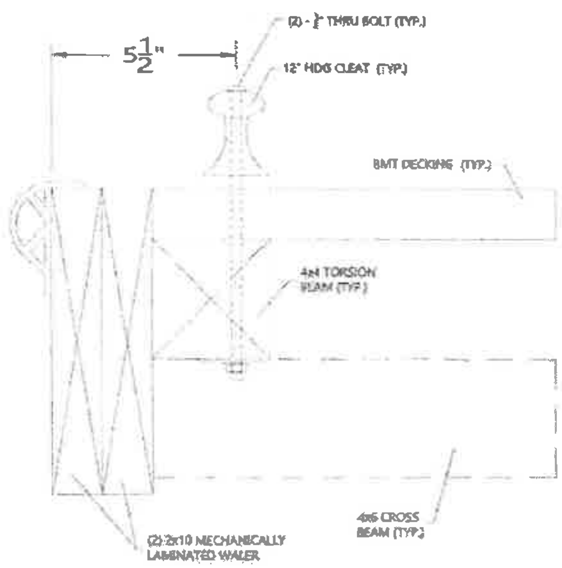
JOB # 8282

Checked By: ______ Date: ______

Revisions:

Drawn by: B.P.R.
Scale: Not To Scale
Date: MAY 21, 2018
MI#: ML-1600000
Sheet: 6 Of 6

NOTES



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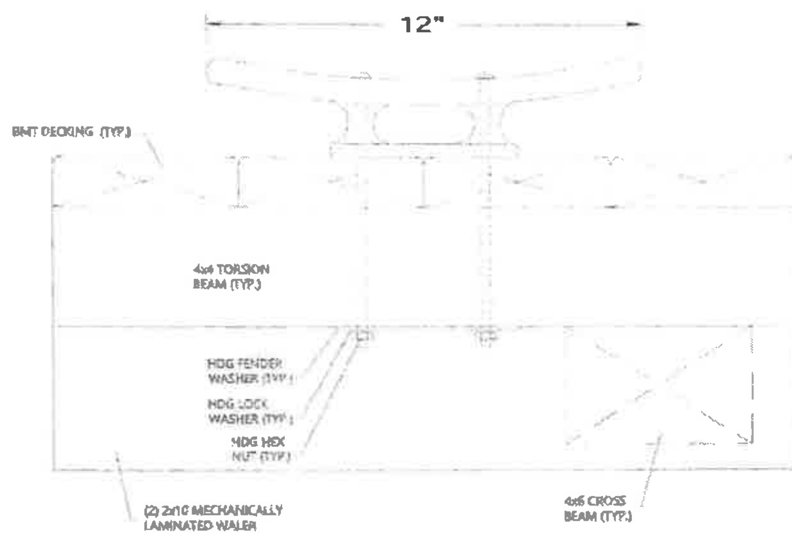

CROSS SECTION B/5

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- ☐ REVISE AN RESUBMIT
- ☐ REJECTED
- ☐ SUBMIT SPECIFIED ITEM

By: [signature] Date: 5-25-16

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MIDDLE ISLAND HOA

BALD HEAD ISLAND
NORTH CAROLINA

CLEAT DETAIL

JOB # 8282

Checked By: ______ Date: ______

Revisions:

Drawn by: B.P.R.
Scale: Not To Scale
Date: MAY 21, 2016
Mil#: ML-1600000
Sheet: 5 Of 6

NOTES

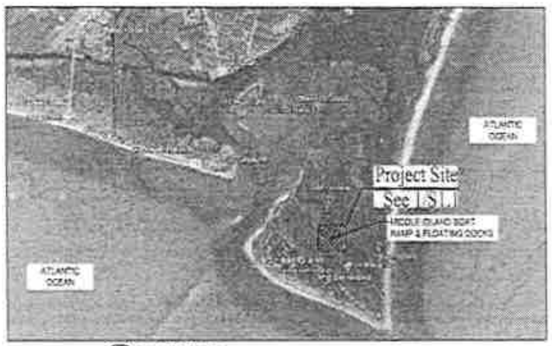
PROPOSED FLOATING DOCK & BOAT RAMP REPAIR

RAMP NOT IN CONTRACT

FOR

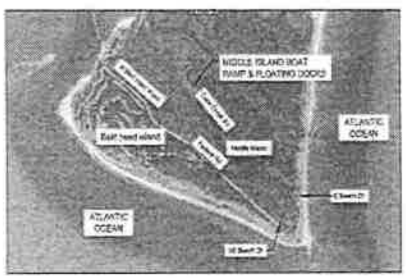
MIDDLE ISLAND HOME OWNER ASSOCIATION, INC.

BALD HEAD ISLAND, NC (MIDDLE ISLAND)

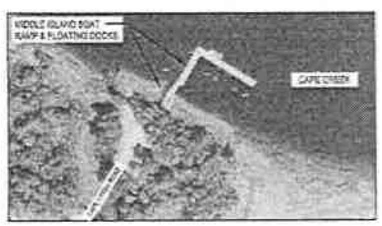


NORTH
VICINITY MAP
NOT TO SCALE

DRAWING INDEX	
S0.0	COVER SHEET - NOTES & MAPS
S1.0	DEMOLITION PLAN
S1.1	NEW WORK PLAN
S2.0	SECTIONS & DETAILS



NORTH
LOCATION MAP
NOT TO SCALE



NORTH
SITE MAP
NOT TO SCALE

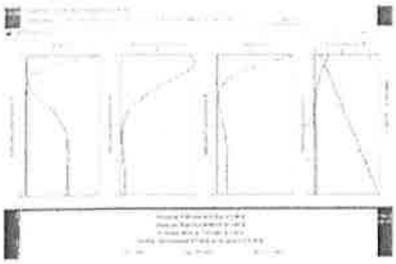
GENERAL NOTES

[illegible]

RAMP NOT IN CONTRACT

CRISER TROUTMAN TANNER

S0.0



Middle Island Marina Dock Report 2-2-20 BMPE Corrected Page 9.pdf
48K

Middle Island Marina Docks Lateral Load Pile Calculations Cases 1M and 3M BMPE seal date 2-2-20.pdf
2223K

Middle Island Marina Docks Marek Drawings 1 of 2 and 2 of 2 seal date 2-2-20.pdf
2876K

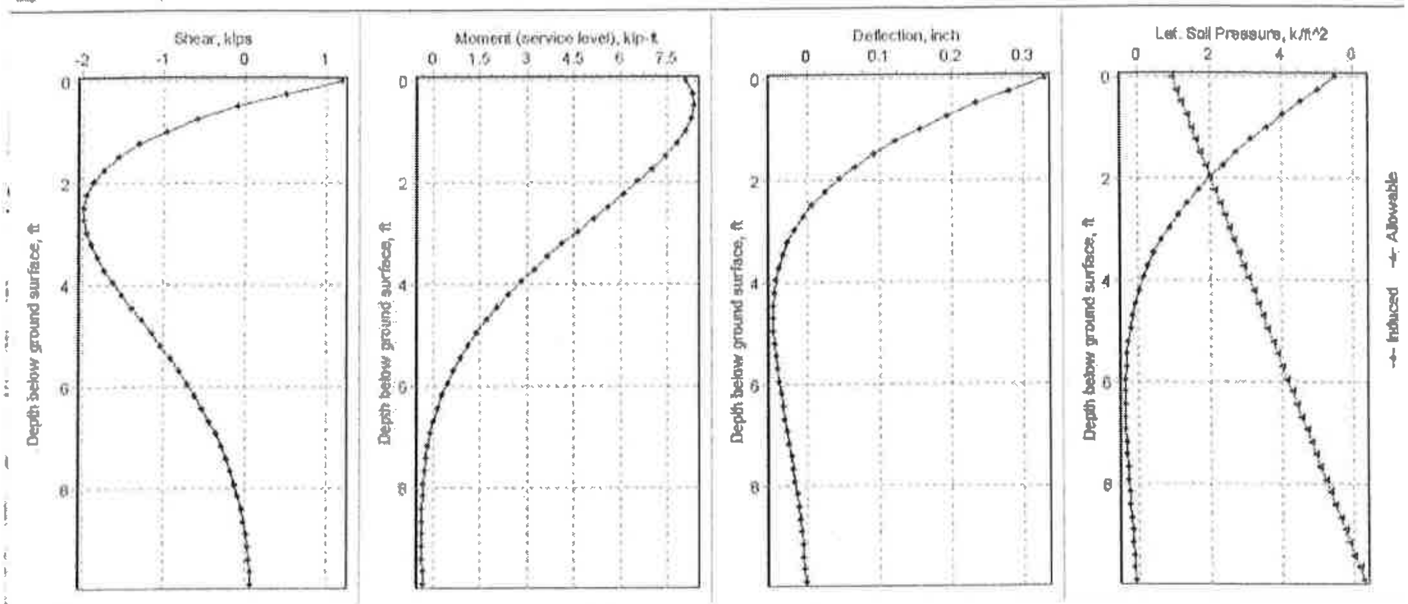
SmallCraftHarborsMilHdbk1025-5 For Shielding Example.pdf
23K

NFPA 303 Section 6 Marina Docks Fire Extinguishers.pdf
434K

Organization: Middle Island POA Cape Creek Marina

Project Name: Occupied Docks 72 mph Wind, 1.5' Waves, 2 FPS CurrentLandward Piles at Low Tide

Lateral Pier Graphs



Maximum Deflection is 0.33 in at 0.00 ft

Maximum Moment is 8.36 k-ft at 0.50 ft

Maximum Shear is -1.98 kips at 2.48 ft

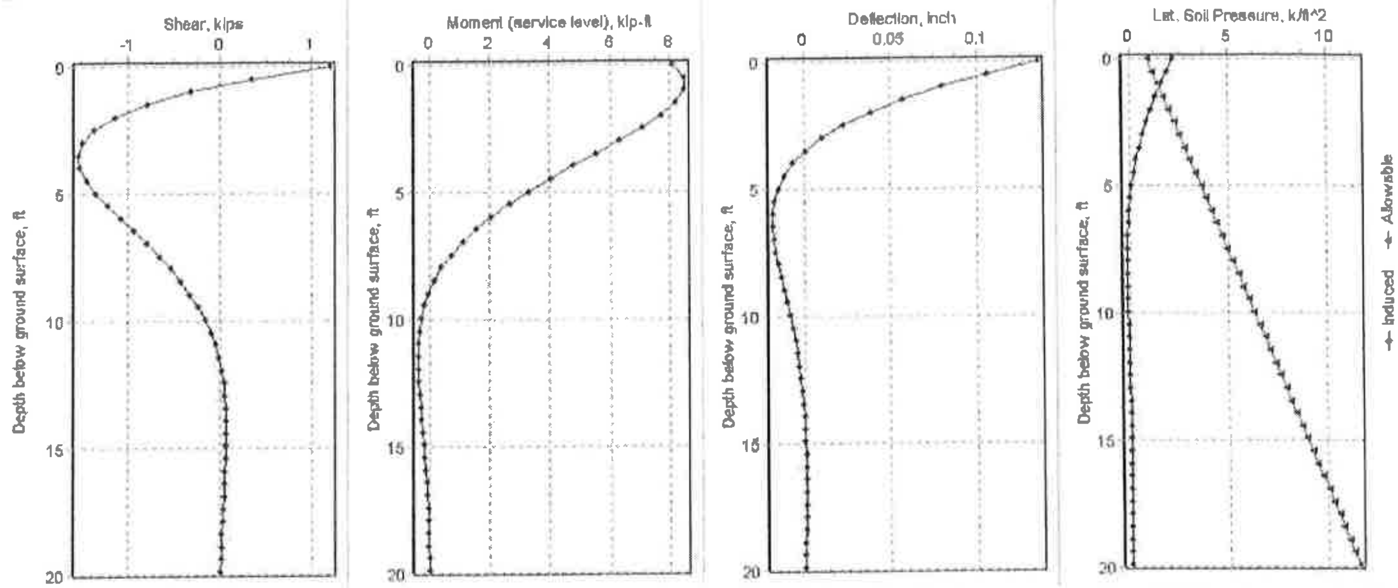
Pier/Pile Tip Movement is 0.00 in at the bottom (9.90 ft)

Organization Middle Island POA Cape Creek Marina

Project Name Occupied Docks 72 mph Wind, 1.5' Waves, 2 FPS Current Landward Piles at Low Tide 45' Piles

Logo

Lateral Pier Graphs



Maximum Deflection is 0.14 in at 0.00 ft

Maximum Moment is 8.48 k-ft at 1.00 ft

Maximum Shear is -1.54 kips at 3.48 ft

Pier/Pile Tip Movement is 0.00 in at the bottom (19.90 ft)

View Table View All Graphs View One Graph

MIDDLE ISLAND MARINA PILE ANALYSIS: Feb 2, 2020

Wind and Waves are assumed Perpendicular to 6' Wide Main Dock — 1M Perp w Boats Low Tide — 72 mph wind — 1.5' Wave Ht — 2 FPS Current

Slips are deemed to be full of appropriate sized boats and floating docks [illegible] to the [illegible] of the wood band board. VBHI would [illegible] have island shut down at 72 mph wind speed

BRUCE MAREK, P.E.
3469 EASTWIND RD
Wilmington, NC 28403

Per CTT Drawing S5.0 Profile Height determined for the associated vessel sizes using ASCE 50 Latest Edition, (2012)

Note: Slips Occupied deemed to mean Full with Boats, but no one on docks as at 72 mph winds Island would be shut down by VBHI

		Wind Speed		Risk Category Table 6-1	Importance Factor Iw	Exposure	Exposure coeff K_z Table 6-3	Topo fctr K_{zt}	Directionality factor K_d Table 6-4	ASCE50 $K_z K_{zt} K_d V^2$ 1 q_z =	Gust Effect G 6.5.8.1	Force coeff C_f Fig 6-20	Design wind pressure $p = q_z G C_f$ psf
Docks											Docks		
Case 1	No Occupancy	= 140 mph	122 knots	I	0.77	C	0.85	1.00	0.85	27.9 psf	0.86	1.20	28.5 psf
Case 2	Slips 100% Occupied	= 72 mph	63 knots	I	0.77	C	0.85	1.00	0.85	7.4 psf	0.86	1.20	7.5 psf
Round Piles											Round Piles		
Case 1	No Occupancy	= 140 mph	122 knots	I	0.77	C	0.85	1.00	0.85	31.2 psf	0.86	1.20	35.5 psf
Case 2	Slips 100% Occupied	= 72 mph	63 knots	I	0.77	C	0.85	1.00	0.85	8.3 psf	0.86	1.20	8.4 psf

Pile Information	Waterward Piles	Landward Piles
Pile Length	36.00 ft	30.00 ft
Avg Embedment Depth	7.40' Embed	9.90' Embed
Appx Butt Diam 3' from Top: 36'=(11"+12")/2,(10"+9")/2 for 30'	11.6"	9.5"
Avg Mudline Diam: Using ASTM D25 Table X1.3 Tapers	8.4"	7.0"
Area at Mudline = (pi*d^2)/4	55.4 in^2	38.5 in^2
Section Mod S=(pi*d^3)/32	58.2 in^3	33.7 in^3
Moment of Inertia I = (pi*d^4)/64	244.4 in^4	117.8 in^4
Appx Tip Diam: for 36' = (7"+8")/2, for 30' = (5"+6")/2	7.6"	5.5"
Average Embedded Diameter d	8.0"	
Average Embedded Diameter b	0.40 ft	0.55 ft

PERPENDICULAR WIND, I.E. OVER WATER FROM WATERWARD (END) TO LANDWARD (WW)

Low Tide Wind — Pile Wind Diam — Pile Wind Diam — Wind Length — 72 mph wind Wind Area — WITH WATERWARD WAVES 8.4 psf

- Waterward Piles: 10.8" avg; 0.90 ft; 15.40 ft; 13.9 sq ft; = 131 lbs per pile; 5; 655 lbs; WATERWARD = 131 lbs per pile; WW Mom Ht 13.90 ft; WW Moment 2607 ft-lbs
- Landward Piles: 8.8" avg; 0.73 ft; 15.40 ft; 11.2 sq ft; = 105 lbs per pile; 6; 545 lbs; LANDWARD = 105 lbs per pile; LW Mom Ht 12.40 ft; LW Moment 1314 ft-lbs

Perpendicular Wind on Finger Dock Ends
Wind Load = Freeboard * Ht * Width x psf
Dock Freeboard Height — Not Tide Dependent — =5*4+4+4+4 — 21.00 ft — Wind Height = — 72 mph wind 7.6 psf 0.80 ft 128 lbs
Waterward Finger Pier Ends — 128 lbs — 13 — = 10 lbs per pile — = 10 lbs per pile — 12.80 ft — 128 ft-lbs — 5.10 ft — 51 ft-lbs

Perpendicular Wind on Boat Ends
Wind Load = Freeboard * Ht * Width x psf
Boat Length — ASCE 50 Slip 1/2 Widths — Not Tide Dependent Boat Profile Height — Boat Wind Area — 72 mph wind 7.5 psf

Boat Length	ASCE 50 Slip 1/2 Widths	Boat Profile Height		Boat Wind Area	Load			Waterward	Landward	WW Mom Ht	WW Moment	LW Mom Ht	LW Moment
22 ft Boat Length	11.00 ft	4.40 ft	5	242.0 sq ft	1815 lbs	1815 lbs	13	= 140 lbs per pile	= 140 lbs per pile	14.40 ft	2016 ft-lbs	6.90 ft	966 ft-lbs
24 ft Boat Length	13.00 ft	4.70 ft	3	183.3 sq ft	1375 lbs	1375 lbs	13	= 106 lbs per pile	= 106 lbs per pile	14.55 ft	1542 ft-lbs	7.05 ft	747 ft-lbs
30 ft Boat Length	9.50 ft	6.20 ft	1	49.4 sq ft	371 lbs	371 lbs	13	= 29 lbs per pile	= 29 lbs per pile	14.80 ft	429 ft-lbs	7.30 ft	212 ft-lbs

Breaking Wave Load on Waterward Piles
Waterward Piles at Low Tide — Cdb =1.75 — 8.9" — Fbrkp = (1/2)*Cdb*Gamma water*D*Hb^2 — Gamma = 64.0 lb/cu ft — 0.83 ft — Wave Ht 1.5 ft Wave Ht 105 lbs — 5 — 525 lbs — = 105 lbs per pile — 12.96 ft — 1360 ft-lbs

Wave Slam On Boat Ends (using Cs=1.0 since not a rigid stucture; FEMA 55 Eqn 8.2 uses Cs=2.0 for houses)
Fs = fs*w = (1/2)*64*Cs*ds*w*h/g
Dock Freeboard Height — Boat Width — Not Tide Dependent Boat Wave Slam Height — Cs = 1.0 Boat Slam Area — 1.5 ft Wave Ht Depth ds = 1.92 ft h = 1.5 ft Wave Ht

Boat Length	Boat Width	Boat Wave Slam Height		Boat Slam Area	Load			Waterward	Landward	WW Mom Ht	WW Moment	LW Mom Ht	LW Moment
22 ft Boat Length	7.50 ft	1.50 ft	5	58.3 sq ft	3458 lbs	3458 lbs	13	= 266 lbs per pile	= 266 lbs per pile	12.96 ft	3445 ft-lbs	6.90 ft	1835 ft-lbs
24 ft Boat Length	8.60 ft	1.50 ft	3	38.0 sq ft	2330 lbs	2333 lbs	13	= 181 lbs per pile	= 181 lbs per pile	12.96 ft	2344 ft-lbs	7.05 ft	1270 ft-lbs
30 ft Boat Length	9.60 ft	1.50 ft	1	14.0 sq ft	879 lbs	879 lbs	13	= 68 lbs per pile	= 64 lbs per pile	12.96 ft	881 ft-lbs	7.30 ft	490 ft-lbs

Wave Slam on Finger Dock Ends (using Cs=1.0 since not a rigid stucture; FEMA 55 Eqn 8.2 Cs=2.0 for houses)
Fs = fs*w = (1/2)*64*Cs*ds*h*w
Not Tide Dependent
Waterward Finger Pier Ends — =5*4+4+4+4 — 21.00 ft — Cs = 1.0 — 1.5 ft Wave Ht Depth ds = 1.92 ft h = 1.5 ft Wave Ht 1935 lbs — 1935 lbs — 13 — = 140 lbs per pile — = 145 lbs per pile — 12.25 ft — 1925 ft-lbs — 4.76 ft — 706 ft-lbs

Design Current — V = 2.0 ft/sec — Current at Mudline = 0.2*V — Fw = 2.83*V knots^2 psf — Avg Diam — Water Depth
Current on WW Piles — V bot = 0.4 ft/sec — V avg = 1.2 ft/sec — = 0.71 knots — 1.4 psf — 0.77 ft — 12.20 ft — 56 lbs — 3 — = 13 lbs per pile
Current on LW Piles — V bot = 0.4 ft/sec — V avg = 1.2 ft/sec — = 0.71 knots — 1.4 psf — 0.61 ft — 4.70 ft — 32 lbs — 3 — = 4 lbs per pile — 6.10 ft — 79 ft-lbs — 2.35 ft — 9 ft-lbs

Current On Boat Ends
Not Tide Dependent — V = 2.0 ft/sec — = 1.18 knots — Fw = 2.83*V knots^2 psf — 3.9 psf
Dock Freeboard Height — Boat Width — Appx Boat Depth = 0.06L — Current Area per ASCE 50 Cd =0.75 — Qty

Boat Length	Boat Width	Appx Boat Depth	Current Area	Qty	Load	Load		Waterward	Landward	WW Mom Ht	WW Moment	LW Mom Ht	LW Moment
22 ft Boat Length	7.60 ft	1.32 ft	7.4 sq ft	5	145 lbs	145 lbs	13	= 11 lbs per pile	= 11 lbs per pile	11.64 ft	127 ft-lbs	4.04 ft	44 ft-lbs
24 ft Boat Length	8.60 ft	1.44 ft	9.2 sq ft	3	107 lbs	107 lbs	13	= 8 lbs per pile	= 8 lbs per pile	11.40 ft	92 ft-lbs	3.96 ft	30 ft-lbs
30 ft Boat Length	9.60 ft	1.80 ft	12.8 sq ft	1	50 lbs	50 lbs	13	= 4 lbs per pile	= 4 lbs per pile	11.30 ft	45 ft-lbs	3.80 ft	15 ft-lbs

Current on Finger Dock Ends
Not Tide Dependent — End Widths =5*4+4+4+4 21.00 ft — V = 2.0 ft/sec Immersed Depth 1.30 ft — = 1.18 knots Immersed Area 27.3 sq ft — Fw = 2.83*V knots^2 psf 3.9 psf 106 lbs
Waterward Finger Pier Ends — 106 lbs — 5 — = 21 lbs per pile — = 0 lbs per pile — 11.55 ft — 245 ft-lbs — 0 ft-lbs

MARINA LATERAL LOAD WITH 72 MPH PERPENDICULAR WIND AND WATERWARD WAVE AND CURRENT LOADS AT LOW TIDE WITH BOATS — 14741 lbs

	Waterward	Landward					
	= 1242 lbs per pile	= 1042 lbs per pile		17164 ft-lbs		7705 ft-lbs	
	= 1.24 kips per pile	= 1.04 kips per pile		17.16 kip-ft		7.71 kip-ft	
Round to Match Soil Program	= 1.20 kips per pile	= 1.00 kips per pile	Round to Match Soil Program	17.16 kip-ft	Round to Match Soil Program	6.16 kip-ft	
			13.82 ft	205200 in-lbs	6.75 ft	97200 in-lbs	

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 15684 BRUCE JAMES MAREK 2-2-20

MIDDLE ISLAND MARINA PILE ANALYSIS: Feb 2, 2020 — 3M Perp w Boats Low Tide — 140 mph wind — 3' Wave Ht

Wind and Waves are assumed Perpendicular to 6' Wide Main Dock

Slips are deemed to be full of appropriate sized boats and floating docks are immersed to the underside of the wood band board. [illegible] would [illegible] when shut down at 72 mph wind speed.

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Per CTT Drawing 50.0 Profile Height determined for the mast anticipated vessel sizes using ASCE 60 Latest Edition, (2012)

Note: Slips Occupied deemed to mean Full with Boats, but no one on docks as at 72 mph winds island would be shut down by VEHI

		Wind Speed		Risk Category Table 1.5-1	Importance Factor Iw	Exposure	Exposure coeff K_z Table 6-3	Topo fctr K_{zt}	Directionality factor K_d Table 6-4	.00256 $K_z K_{zt} K_d V^2$ q_z =	Gust Effect G 6.5.8.1	Force coeff C_f Fig 6-20	Design wind pressure $p = q_z G C_f$ psf
Docks											Docks		
Case 1	No Occupancy	= 140 mph	122 knots	I	0.77	C	0.85	1.00	0.85	27.0 psf	0.85	1.20	28.5 psf
Case 2	Slips 100% Occupied	= 72 mph	63 knots	I	0.77	C	0.85	1.00	0.85	7.4 psf	0.86	1.20	7.5 psf
Round Piles											Round Piles		
Case 1	No Occupancy	= 140 mph	122 knots	I	0.77	C	0.86	1.00	0.85	31.2 psf	0.85	1.20	33.6 psf
Case 2	Slips 100% Occupied	= 72 mph	63 knots	I	0.77	C	0.86	1.00	0.85	8.3 psf	0.86	1.20	9.4 psf

Pile Information	Waterward Piles	Landward Piles
Pile Length	35.00 ft	30.00 ft
Avg Embedment Depth	7.40' Embed	8.60' Embed
Approx Butt Diam 3' from Top: 35'=(11"+12")/2,(10"+9")/2 for 30'	11.6"	9.5"
Avg Mudline Diam, Using ASTM D25 Table X1.3 Tapers	8.4"	7.0"
Area at Mudline = (pi*d^2)/4	55.4 in^2	38.5 in^2
Section Mod S=(pi*d^3)/32	58.2 in^3	33.7 in^3
Moment of Inertia I = (pi*d^4)/64	244.4 in^4	117.8 in^4
Approx Tip Diam for 35' = (7"+8")/2, for 30' = (5"+6")/2	7.6"	6.6"
Average Embedded Diameter d	8.0"	
Average Embedded Diameter b	0.66 ft	0.55 ft

PERPENDICULAR WIND, I.E. OVER WATER FROM WATERWARD (ENE) TO LANDWARD (WSW) — WITH WATERWARD WAVES ON FINGER DOCK ENDS AND MAIN DOCK INSIDES

Low Tide Wind	Pile Wind Diam	Pile Wind Diam	Wind Length	140 mph wind Wind Area					WATERWARD	LANDWARD	WW Mom Ht	WW Moment	LW Mom Ht	LW Moment
Waterward Piles	10.8" avg	0.90 ft	15.40 ft	13.9 sq ft	38.8 psf = 465 lbs per pile	5	2479 lbs		= 456 lbs per pile		12.90 ft	9851 ft-lbs		
Landward Piles	8.8" avg	0.73 ft	15.40 ft	11.2 sq ft	= 399 lbs per pile	8	3192 lbs			= 395 lbs per pile			12.40 ft	4948 ft-lbs
Perpendicular Wind on Finger Dock Ends														
Wind Load = Freeboard * Ht * Width * psf					140 mph wind									
Dock Freeboard Height — Not Tide Dependent		=5+4+4+4+4			28.5 psf									
Waterward Finger Pier Ends		21.00 ft		Wind Height =	1.60 ft									
					958 lbs		958 lbs	13	= 74 lbs per pile	= 74 lbs per pile	13.00 ft	962 ft-lbs	5.60 ft	407 ft-lbs
Wave Slam on Main Dock Insides (using Cs=1.0 since not a rigid structure; FEMA 55 Eqn 8.7 Cs=2.0 for houses)														
Fs = fs*w = (1/2)*64*Cs*ds*h*w					3.0 ft Wave Ht									
Not Tide Dependent		=22+22+22 [illegible]		Cs = 1.0	Depth ds = 2.65 ft									
Main Dock Inside Length		62.00 ft			h = 3.1 ft Dock Ht									
					23802 lbs		23802 lbs	13	= 1831 lbs per pile	= 1831 lbs per pile	13.00 ft	23803 ft-lbs	6.50 ft	10071 ft-lbs
Wave Slam on Landward Piles														
Fs = fs*w = (1/2)*64*Cs*ds*h*w					3.0 ft Wave Ht									
Tide Dependent: Diam at Wave	7.8"	0.65 ft		Cs = 1.2	Depth ds = 3.95 ft									
					h = 3.0 ft Wave Ht									
					= 753 lbs per pile	3	2506 lbs	8		= 288 lbs per pile		0 ft-lbs	4.20 ft	1750 ft-lbs

MARINA LATERAL LOAD WITH 140 MPH PERPENDICULAR WIND AND 3' WAVES, AT LOW TIDE, WITHOUT BOATS		WATERWARD	LANDWARD					
	32133 lbs	= 2400 lbs per pile	= 2592 lbs per pile					1750 ft-lbs
		= 2.40 kips per pile	= 2.59 kips per pile		34616 ft-lbs			17212 ft-lbs
Matches Soil Program		= 2.40 kips per pile	= 2.59 kips per pile		34.60 kip-ft			17.22 kip-ft
		Wind firm should be	= 2.61 kips per pile	To Match Soil Program	34.60 kip-ft	Matches Soil Program		18.29 kip-ft
						Wind firm should be		17.20 kip-ft
				13.21 ft	415200 in-lbs	5.45 ft		206400 in-lbs

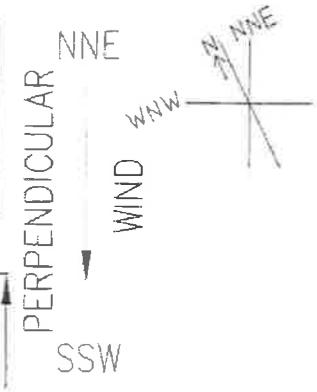
Note: Only Pages 8&9 in 2-2-20 Report [illegible] had LW Pile Lateral Load as 2.36 kips and LW Pile Moment as 14.2 kip-ft; 2.6 kips and 17.2 kip-ft are correct values. Report page 9 of 10 has been [illegible] been corrected for pile [illegible] and F.S. and [illegible] on page 9 corrected 2-2-20

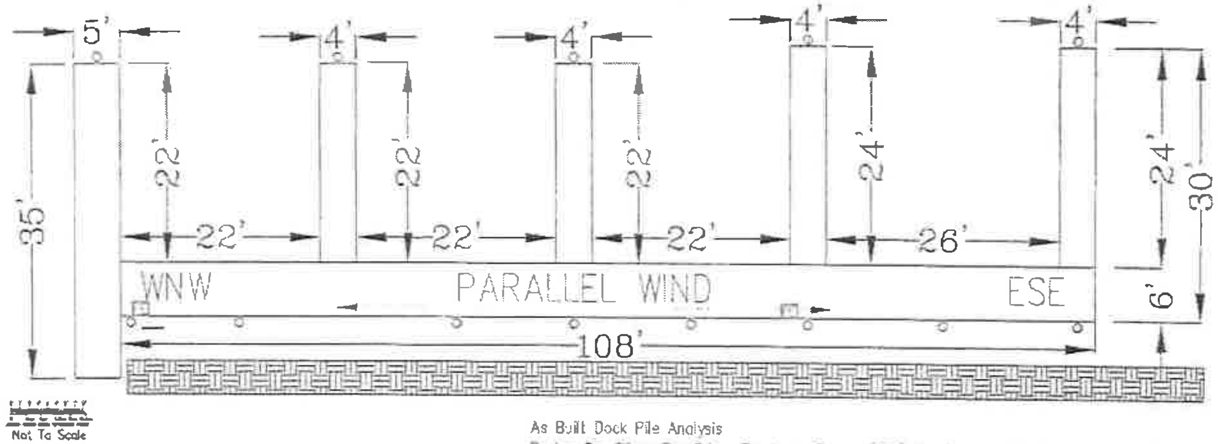
NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 15684 BRUCE [illegible] MAREK

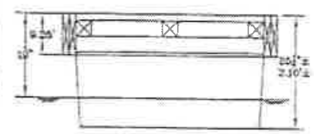
2-2-20

Bruce Marek

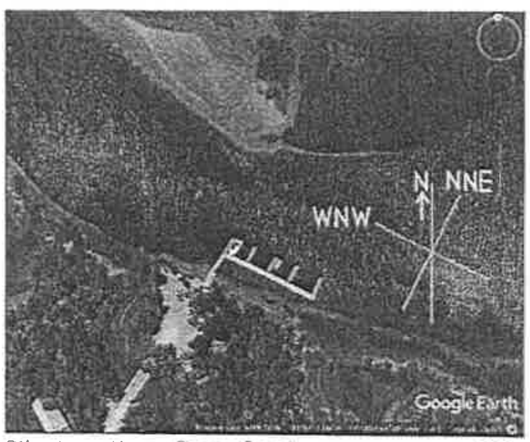
MIDDLE ISLAND MARINA DOCK CALCULATIONS – 2-2-2020







TYP DEADLOAD FLOTATION CONDITION
30 PSF LL PER ASCE 50 PAGE 224
RESTRICTED ACCESS PEDESTRIAN DOCK
NO SCALE



Site Location: Cape Creek, Middle Island, NC

As Built Dock Pile Analysis

Design Conditions Per Criser Troutman Tanner (CTT) drawings, seal date 3/6/13, Jeff Troutman, P.E.
Use of CTT drawings allowed per Troutman e-mail, 9-3-19 (CTT is now Ardurra Group NC).
Site Measurements 8-29-19, 2 pm+. VBHI Bldg Inspector in attendance
Follow-Up Site Visit post Hurricane Dorian on Oct. 18, 2019 BMPE.

Boats: Per Dock Plan: Length 22', Qty 5; Length 24', Qty 3; Length 30', Qty 1; = 9 vessels.
ASCE 50 Planning and Design Guidelines for Small Craft Harbors, Third Edition (2012)
Vessel Weight (Appx)=12*L^2. For 22' Length, Wt=5808 lbs; 24'L, Wt=6912 lbs; 30'L, Wt=10,800 lbs
Profile Ht: Page 219 Fig 3.15 Tobiasson 1989 Lower Curve: 22'L=4.4'Ht; 24'L=4.7'Ht; 30'L=5.2'
(UFC 2009 Profile Ht = 0.15L: 22'L=3.3'; 24'L=3.6'; 30'L=4.5')
Using Grady/White typical vessel beams: 22'L=7.5'B; 24'L=8.5'B; 30'L=9.5'B
Vessel draft d = appx 0.06L (Marek): 22'L=1.32'd; 24'L=1.44'd; 30'L=1.80'd

Appx Midships Underbody Area for Current: Beam*Depth*0.6:
=6 sf for 22'; =7 sf for 24'; =11 sf for 30'
Profile Underbody: Length*Depth*0.8 = 26 sf for 24';= 26 sf for 24'; = 44 sf for 30'
For Current, from ASCE 50 page 220., Cd=0.6 for head on; 0.8 for broadside;
Cd = 0.75 if current & vessel directions not aligned. (These are used in place of shape factors)

For Vessel Wind Areas Per ASCE 50: Perpendicular Wind = Profile Ht x Slip Water Width.
For Parallel Wind = Profile Ht x Slip Length;Shielding factor of .2 for multiple rows (page 217=220).
Wind Drag Coefficient Cd: Bow Wind 0.5–1.2; Wind Abeam 0.8–1.5; Wind Astern 0.5–1.2.
Conservatively/For Simplicity Assume Cd=1.0.

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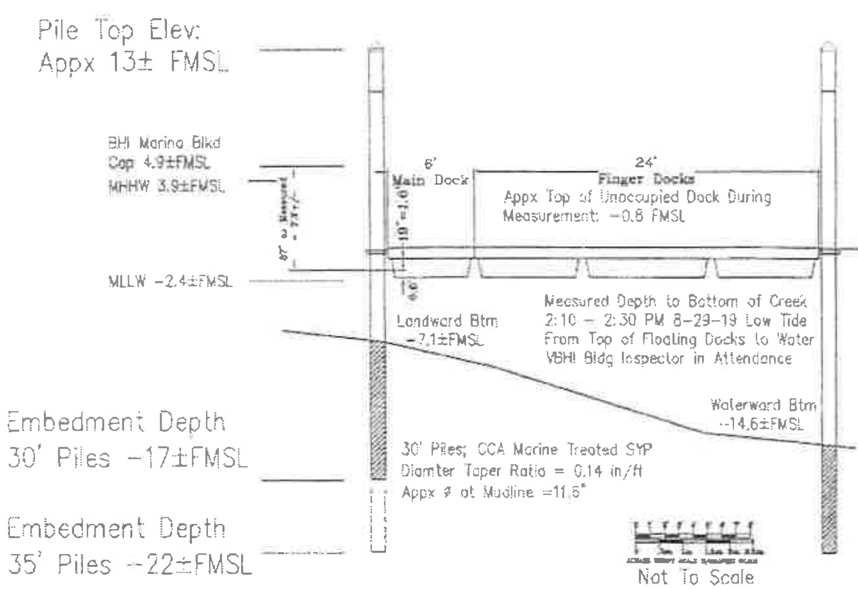
MIDDLE ISLAND MARINA DOCKS
AS BUILT CONFIGURATION: Cross Section



Docktop to Water	Creek Btm	Embed
30' L1 = 7.9'	-8.7 FMSL	8.3'
30' L2 = 9.3'	-10.1 FMSL	6.9'
35' L3*= 8.5'	-9.3 FMSL	12.7'
30' L4 = 7.9	-8.7 FMSL	8.3'
30' L5 = 6.8'	-7.5 FMSL	9.5'
30' L6 = 6.2'	-7.0 FMSL	10.0'
30' L7 = 4.9'	-5.7 FMSL	11.3'
30' L8 = 3.8'	-4.5 FMSL	12.5'

L3 is a 35' pile per Tommy Perry
See Dock Layout plans for pile numbering.(May be L2)

Docktop to Water	Creek Btm	Embed
35' W1 = 13.0'	-13.8 FMSL	8.2'
35' W2 = 15.0'	-15.8 FMSL	6.2'
35' W3 = 14.1'	-14.9 FMSL	7.1'
35' W4 = 13.9'	-14.7 FMSL	7.3'
35' W5 = 13.2'	-14.0 FMSL	8.0'

Sum of Pile Embedments = 116.3'
/13 total piles = 8.95' avg Embed
Sum of Landward Pile Embedments =79.5'
/8 piles = 9.9' avg Embed
Sum of Waterward Pile Embedments =36.8'
/5 piles = 7.4' avg embed

Note: Bald Head Island Marine Bulkhead Cap = 4.9 FMSL NAVD 88 (Which was 6.0 FMSL+/- NGVD 29)
Ferry Terminal "Gate A" landing is 12" below bulkhead cap = 3.9 FMSL. It will typically be closed down a few times a year at high tide, typically at a "king tide" or with storm driven wave build up. Thus it is a good estimation of MHHW, or close enough for these calculations. At time of measuring at Middle Island Marina, BHI Harbormaster simultaneously measured 84" down to water from blkd cap. ("Gate B" Contractor Landing is set at appx bulkhead cap height, so is used when Gate A is closed for high water).

Bald Head Island Marina Piles, predominately 30' and 35' piles, (except at the ferry terminal, barge, A-Dock 100' slips and fuel dock), are 7' to 8' abv marina bulkhead cap, = pile top elevation of appx 12.0' to 13.0' FMSL.

Appx MHHW =3.9'; MHHW to Middle Island Marina Pile Top =9.1'±.
From Online Monthly Full Year Tide Range:
+5.8' Max to -0.5' =6.3' Tide Range.
+3.9 FMSL -6.3 = MLLW = -2.4 FMSL
Appx MLLW to Pile Top = 15.4'±

ASTM D25-12(2017) From Table X1.3: Specified Butt Circumference with Corresponding Min Tip Circumferences for Southern Yellow Pine Piles:(Butt Circumference measured at 3' from Butts, which is top of pile)
For 35' Length, 35" circumference (11" Butt diameter at 3' from top), Min Tip Circumference = 22" = 7.0" diam.
For 35' Length, 38" circumference (12" Butt diameter at 3' from top), Min Tip Circumference = 25" = 8.0" diam. Installed 35' Piles avg Buttø =11.5"±; Tip Assumed 7.5"ø. Diamter Taper Ratio = 0.125" per ft.
Appx ø at Mudline =8.4"
Appx ø at MLLW = 5.9"; Avg ø Mud to MLLW = 9.2"
Appx ø at MHHW = 10.7"; Avg ø Mud to MLLW= 9.6"
Pile Avg ø Pile Top to MHHW =11.2"; to MLLW =10.8"

ASTM D25-12(2017) From Table X1.3: Specified Butt Circumference with Corresponding Min Tip Circumferences for Southern Yellow Pine Piles:(Butt Circumference measured at 3' from Butts, which is top of pile)
For 30' Length, 31" circumference (10" Butt diameter at 3' from top), Min Tip Circumference = 19" = 6.0" diam.
For 30' Length, 28" circumference (9" Butt diameter at 3' from top), Min Tip Circumference = 16" = 5.1" diam.
Installed 30' Piles Diamter Taper Ratio = 0.146" per ft.
Appx ø at Mudline =7.0"
Appx ø at MLLW = 7.7"; Avg ø Mud to MLLW = 7.3"
Appx ø at MHHW = 8.6"; Avg ø Mud to MHHW= 7.8"
Pile Avg ø Pile Top to MHHW =9.2"; to MLLW =8.8"

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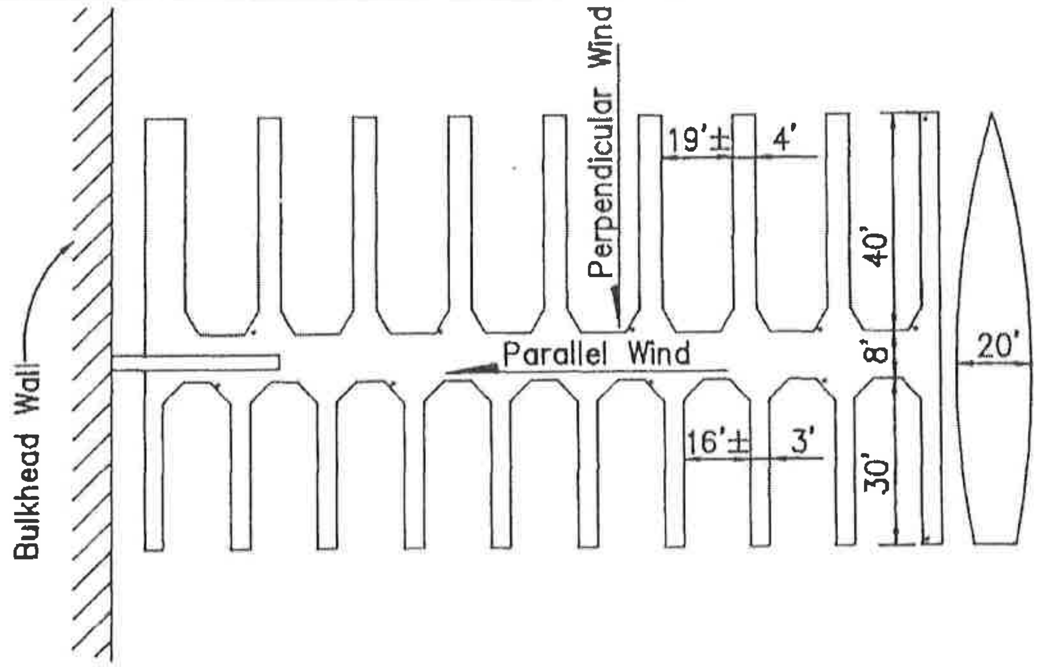

NOT TO SCALE

° Design Wind Load: 15 PSF

° Perpendicular Wind

40' Boats:	8 Each x 19' Beam x 5.5' Height x 15 PSF	=	12,540 Lbs.
Fingers:	9 Each x 4' Beam x 1.5' Height x 15 PSF	=	810 Lbs.
Multiply by 1.5 for Row of 30' Boats = 1.15 x 13,350 Lbs.		=	15,352.5 Lbs.
78' Boat:	20' Beam x 7.4' Height x 15 PSF	=	2,220.O Lbs.
	TOTAL PERPENDICULAR LOAD:	=	17,572.5 Lbs.

° Parallel Wind

78' Boats:	78' Each x 7.5' Beam x 15 PSF	=	8,658 Lbs.
40' Boats:	8 Each x 40' x 5.5' Height x 3 PSF	=	5,280 Lbs.
30' Boats:	10 Each x 30' x 4.8' Height x 3 PSF	=	4,320 Lbs.
	TOTAL PARALLEL LOAD:		18,258 Lbs.

° Reckon Parallel windloading for Design

Figure 15
Sample Calculation for Windloading on a Floating Pier System

6.1 Portable Fire Extinguishers.

6.1.1 Placement.

6.1.1.1

Placement of portable fire extinguishers shall be in accordance with Chapter 5 of NFPA 10 unless otherwise permitted by 6.1.1.1.1, 6.1.1.1.2, or 6.1.1.1.3.

6.1.1.1.1

Placement of portable fire extinguishers on piers and along bulkheads where vessels are moored or are permitted to be moored shall meet the following criteria:

(1) Extinguishers listed for Class A, Class B, and Class C fires shall be installed at the pier/land intersection on a pier that exceeds 25 ft (7.62 m) in length.
(2) Additional fire extinguishers shall be placed such that the maximum travel distance to an extinguisher does not exceed 75 ft (22.86 m).
(3) Extinguishers shall be protected from environmental exposures to prevent damage and lack of operability.

6.1.1.1.2 Fuel-Dispensing Areas.

6.1.1.1.2.1

Portable fire extinguishers that meet the minimum requirements of Chapter 5 of NFPA 10 for extra (high) hazard type shall be installed on two sides of a fuel-dispensing area.

6.1.1.1.2.2

On piers or bulkheads where long fueling hoses are installed for fueling vessels, additional extinguishers installed on piers or bulkheads shall meet the requirements of Chapter 5 of NFPA 10 for extra (high) hazard type and 6.1.1.1.1 of this standard.

6.1.1.1.3

All extinguishers installed on piers shall meet the rating requirements set forth in Chapter 5 of NFPA 10 for ordinary (moderate) hazard type.

6.1.2 Visibility and Identification.

All portable fire extinguishers shall be clearly visible and marked.