

# Lateral Resistance of Helical Foundations for Hurricane Prone Coastal Areas

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## Outline

- IBC Wind Design
- Lateral Load Resistance of Piles
- Lateral Load Tests on Helical Piles
- Example Lateral Load Design

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# Simplified Wind Loads

- Design Wind Pressure,  $P_s$

$$- P_s = \lambda I p_{s30}$$

Where      $\lambda$  = Adjustment Factor

I = Importance Factor

$p_{s30}$  = Wind Pressure at 30 ft,  
Exposure B

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## Adjustment Factors, (IBC 2006)

**Adjustment Factor  
for Building Height and Exposure,  $\lambda$**

Mean roof height (ft)	Exposure		
	B	C	D
15	1.00	1.21	1.47
20	1.00	1.29	1.55
25	1.00	1.35	1.61
30	1.00	1.40	1.66
35	1.05	1.45	1.70
40	1.09	1.49	1.74
45	1.12	1.53	1.78
50	1.16	1.56	1.81
55	1.19	1.59	1.84
60	1.22	1.62	1.87

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# Exposure Definitions

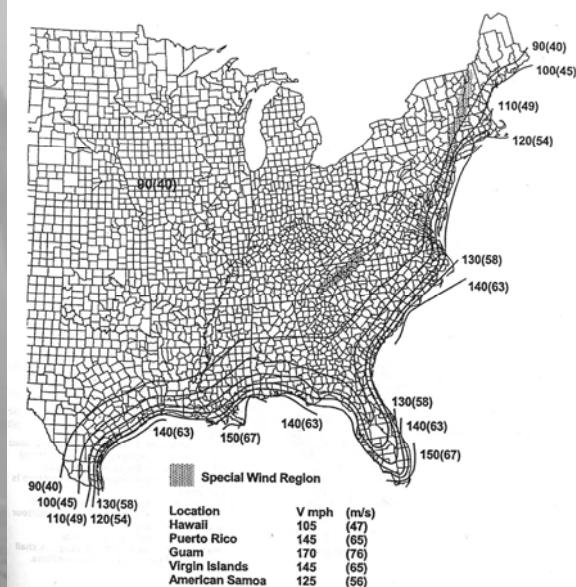
- Exposure B – Urban & Dense Suburban
- Exposure C – Open Terrain
- Exposure D – Shoreline, Flats, Lakes

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## Basic Wind Speed, 3s Gust (IBC 2006)



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## Design Wind Pressures, (IBC 2006)

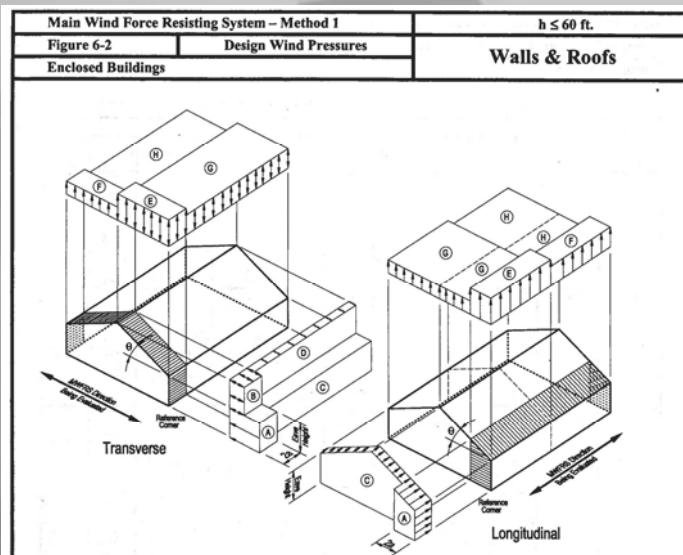
Main Wind Force Resisting System – Method 1				$h \leq 60$ ft.															
Figure 6-2 (cont'd) Design Wind Pressures			Walls & Roofs																
Enclosed Buildings																			
Simplified Design Wind Pressure , $p_{50}$ (psf) (Exposure B at $h = 30$ ft. with $i = 1.0$ )																			
Basic Wind Speed (mph)	Roof Angle (degrees)	Load Case		Zones								Eoh	Goh						
				A	B	C	D	E	F	G	H								
140	0 to 5°	1	31.1	-16.1	20.6	-9.6	-37.3	-21.2	-26.0	-16.4	-52.3	-40.9							
	10°	1	35.1	-14.5	23.3	-8.5	-37.3	-22.8	-26.0	-17.5	-52.3	-40.9							
	15°	1	39.0	-12.9	26.0	-7.4	-37.3	-24.4	-26.0	-18.6	-52.3	-40.9							
	20°	1	43.0	-11.4	28.7	-6.3	-37.3	-26.0	-26.0	-19.7	-52.3	-40.9							
	25°	1	39.0	6.3	28.2	6.4	-17.3	-23.6	-12.5	-19.0	-32.3	-27.5							
	30 to 45	1	35.0	23.9	27.8	19.1	2.7	-21.2	0.9	-18.2	-12.3	-14.0							
150	30 to 45	2	35.0	23.9	27.8	19.1	13.4	-10.5	11.7	-7.5	-12.3	-14.0							
	0 to 5°	1	35.7	-18.5	23.7	-11.0	-42.9	-24.4	-29.8	-18.9	-60.0	-47.0							
	10°	1	40.2	-16.7	26.8	-9.7	-42.9	-26.2	-29.8	-20.1	-60.0	-47.0							
	15°	1	44.8	-14.9	29.8	-8.5	-42.9	-28.0	-29.8	-21.4	-60.0	-47.0							
	20°	1	49.4	-13.0	32.9	-7.2	-42.9	-29.8	-29.8	-22.6	-60.0	-47.0							
	25°	1	44.8	7.2	32.4	7.4	-19.9	-27.1	-14.4	-21.8	-37.0	-31.6							
170	30 to 45	2	—	—	—	—	-7.5	-14.7	-2.1	-9.4	—	—							
	0 to 5°	1	45.8	-23.8	30.4	-14.1	-55.1	-31.3	-38.3	-24.2	-77.1	-60.4							
	10°	1	51.7	-21.4	34.4	-12.5	-55.1	-33.6	-38.3	-25.8	-77.1	-60.4							
	15°	1	57.6	-19.1	38.3	-10.9	-55.1	-36.0	-38.3	-27.5	-77.1	-60.4							
	20°	1	63.4	-16.7	42.3	-9.3	-55.1	-38.3	-38.3	-29.1	-77.1	-60.4							
	25°	1	57.5	9.3	41.6	9.5	-25.6	-34.8	-18.5	-28.0	-47.6	-40.5							
30 to 45	30 to 45	2	—	—	—	—	-9.7	-18.9	-2.6	-12.1	—	—							
	30 to 45	1	51.5	35.2	41.0	28.2	4.0	-31.3	1.3	-26.9	-18.1	-20.7							
30 to 45	30 to 45	2	51.5	35.2	41.0	28.2	19.8	-15.4	17.2	-11.0	-16.1	-20.7							

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## Design Wind Pressure, (IBC 2006)



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# Lateral Capacity

Puri, Stephenson, Dziedzic, and Goen (1984)

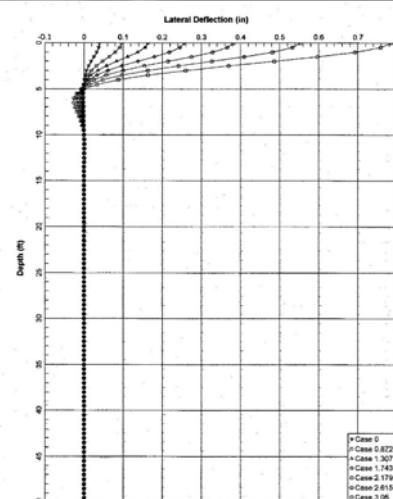
- Helix piers can develop significant lateral resistance and this resistance is governed by shaft diameter
- Modified equations for p-y curves by Matlock & Reese
- Applied Cu parameter to account for disturbance

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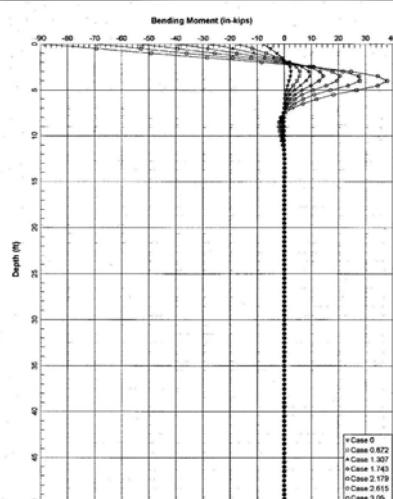
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# Lateral Load Resistance of Piles



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### Input Parameters for Different Soil Types

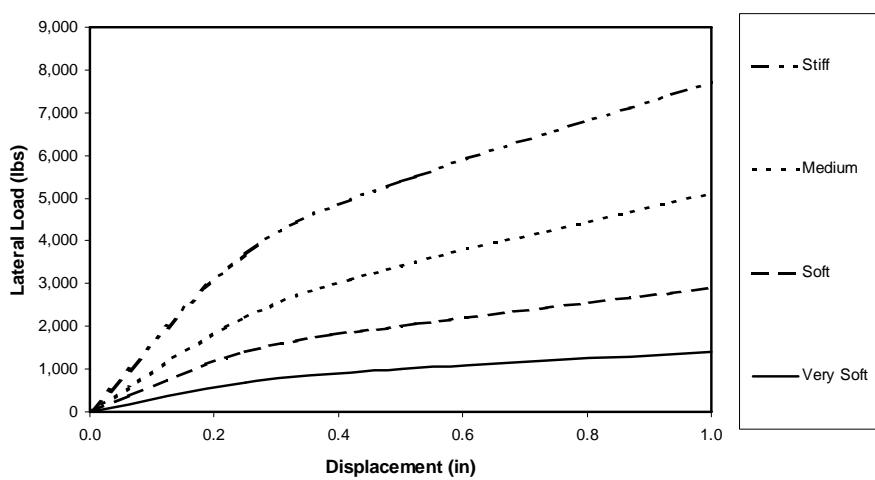
	SPT Blow Count (blows/ft)	Unit Weight (pcf)	Horiz. Mod. of Subgrade Reaction (pci)	Angle of Friction (deg)	Cohesion (psf)	Strain at 50% Peak Strength (in/in)
Sand	Very Loose	0-4	70	5	25	-
	Loose	4-10	96	25	29	-
	Medium	10-30	110	90	33	-
	Dense	30-50	130	225	39	-
Clay	Very Soft	0-2	82	30	-	200
	Soft	2-4	86	100	-	400
	Medium	4-8	92	500	-	800
	Stiff	8-15	104	1000	-	1500

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## Lateral Resistance Clay Soils

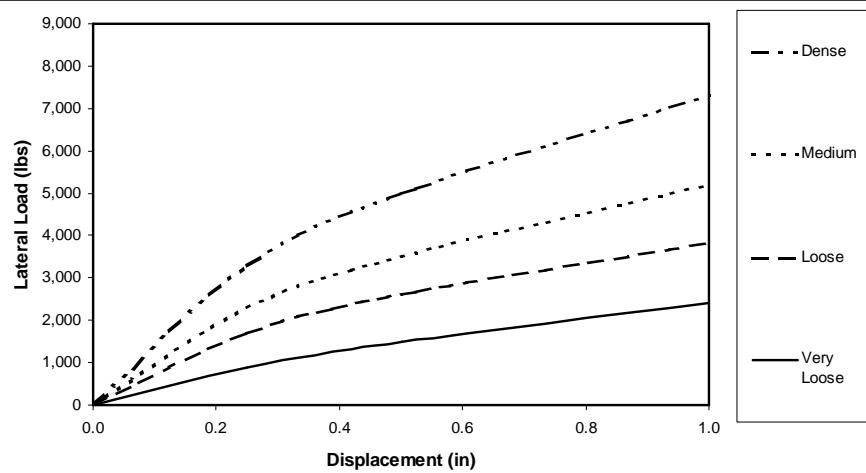


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## Lateral Resistance Sand Soils

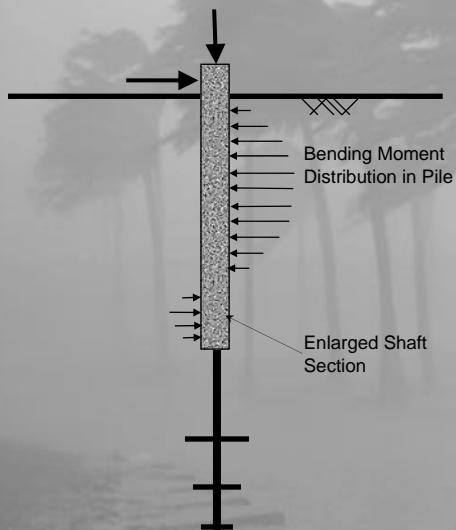


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## Lateral Load Enhancement



### Analysis Methods:

1. Broms
2. Brinch-Hansen
3. p-y Methods
4. Finite Difference
5. Finite Element

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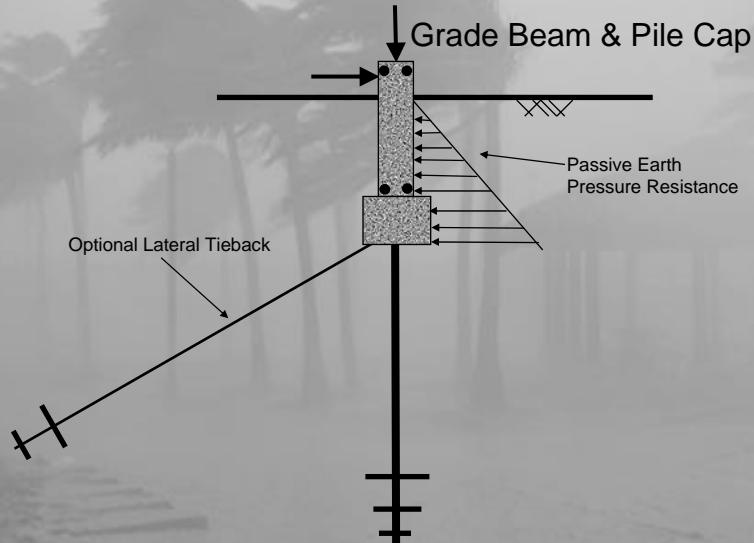
## Concrete Enhanced Helical Pier Lateral Loads

Allowable Lateral Load (kips)			
Post Diameter in	Post Length		
	3 ft	6 ft	
Med. Stiff Clay (c=800 psf)	12	4.0	8.0
	18	5.3	10.7
	24	6.7	12.7
Stiff Clay (c=1500 psf)	12	7.3	14.0
	18	9.3	18.7
	24	10.7	22.7
Loose Sand (phi=29)	12	na	3.3
	18	0.5	4.7
	24	0.7	5.3
Dense Sand (phi=39)	12	0.7	6.7
	18	1.3	8.7
	24	2.7	10.7

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## Lateral Load Enhancement

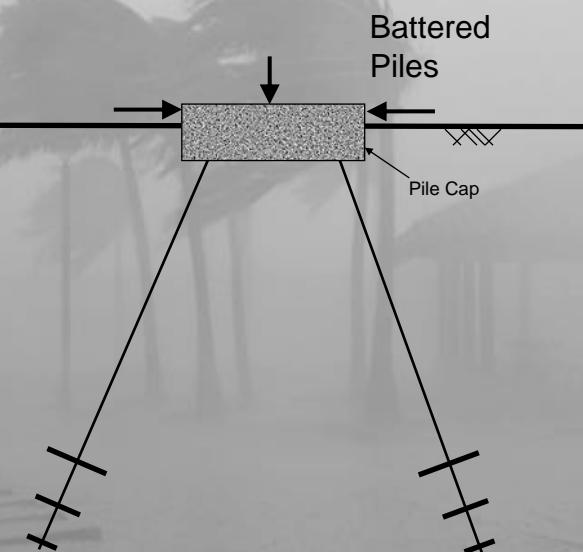


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## Lateral Load Enhancement



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# Lateral Load Testing

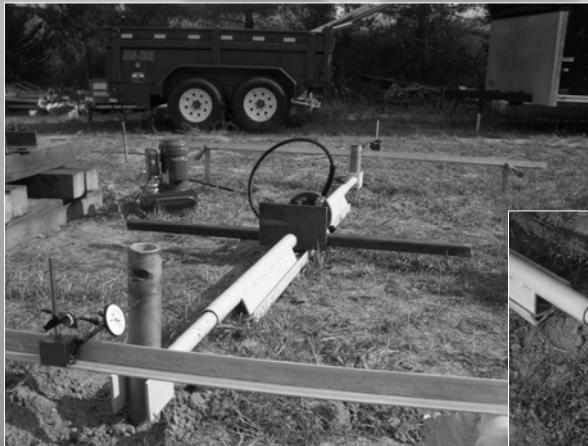


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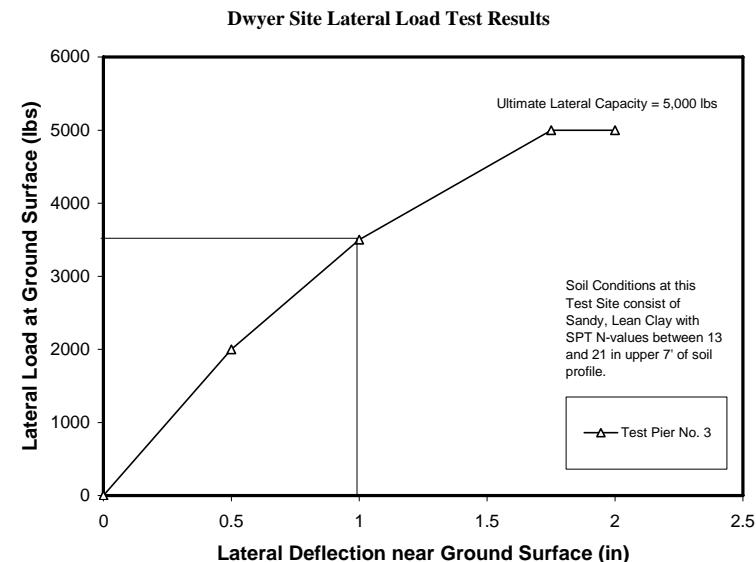
# Lateral Load Testing



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## Lateral Load Test Results

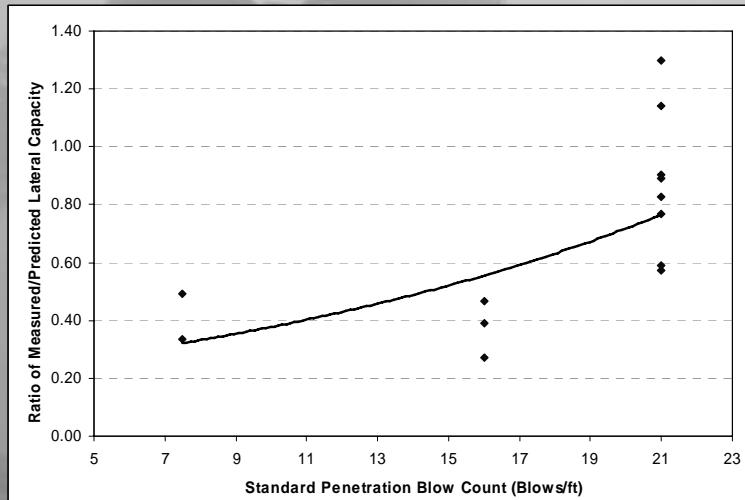
Site	Soil Condition	Average N-Value	Design Capacity		Pile Depth	Lead Configuration	Ratio
			Theoretical	Measured			
University of Cincinnati, Ohio	Silty Clay Fill	7.5	2550	1250	16	12" DCE	0.49
University of Cincinnati, Ohio	Silty Clay Fill	7.5	2550	850	10	10" & 12" Circular	0.33
Dwyer Lot	Sandy Clay	16	3850	1800	na	na	0.47
Dwyer Lot	Sandy Clay	16	3850	1500	18	8", 10", 12" DCE	0.39
Dwyer Lot	Sandy Clay	16	3850	1050	12	8", 10", 12" Circular	0.27
West Chester Lot	Clay	21	3850	2955	12	8" Circular	0.77
West Chester Lot	Clay	21	3850	3485	12	8" Circular	0.91
West Chester Lot	Clay	21	3850	5000	12	8" Circular	1.30
West Chester Lot	Clay	21	3850	3430	12	8" Circular	0.89
West Chester Lot	Clay	21	3850	2200	12	8" Circular	0.57
West Chester Lot	Clay	21	3850	4400	12	8" Circular	1.14
West Chester Lot	Clay	21	3850	2265	12	8" Circular	0.59
West Chester Lot	Clay	21	3850	3185	12	8" Circular	0.83
							Average = 0.69

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## Lateral Load Test Results



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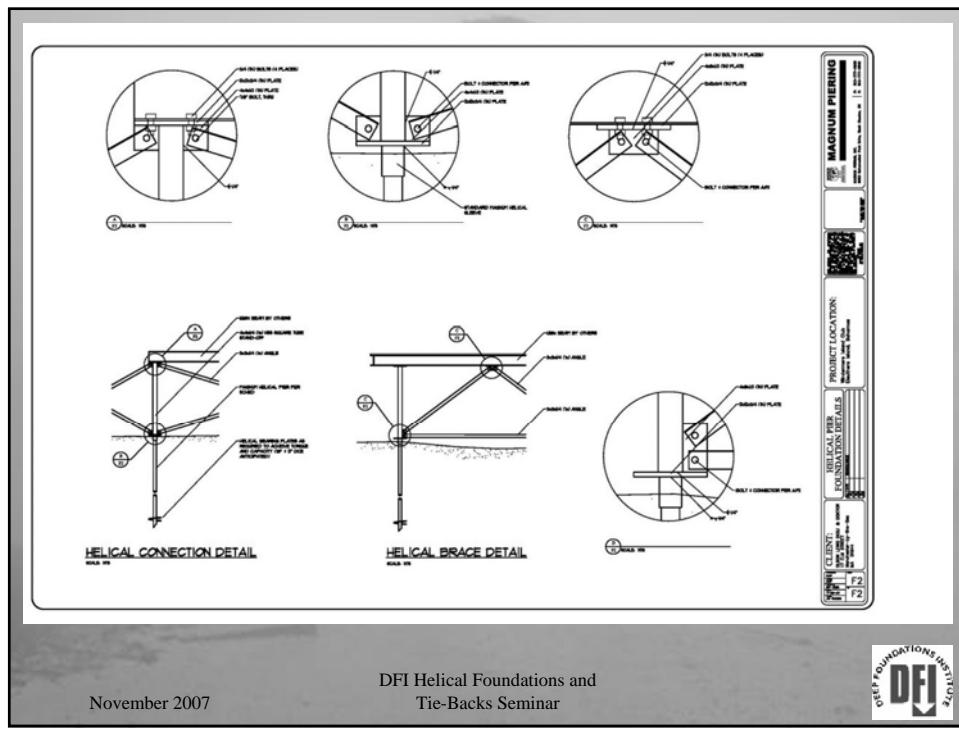
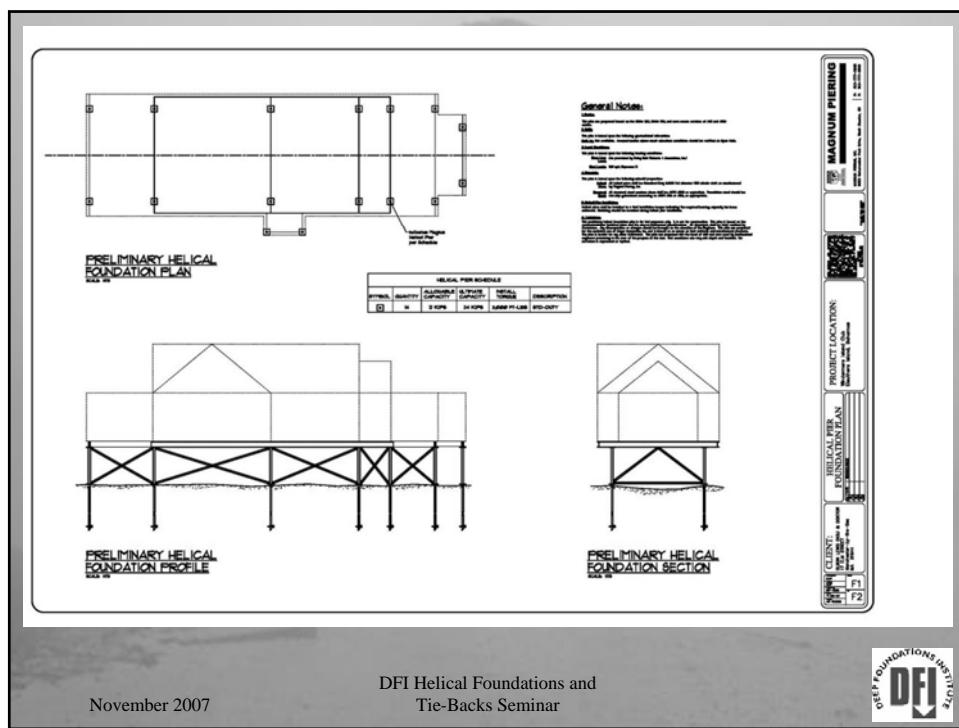
## Example Lateral Load Design

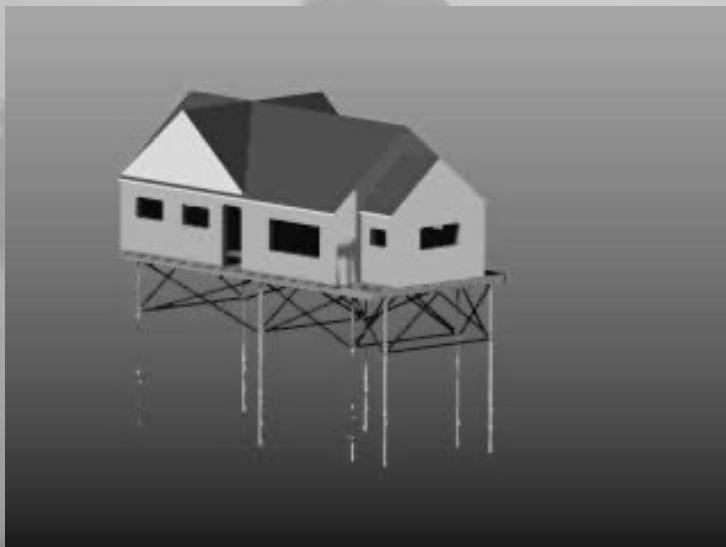


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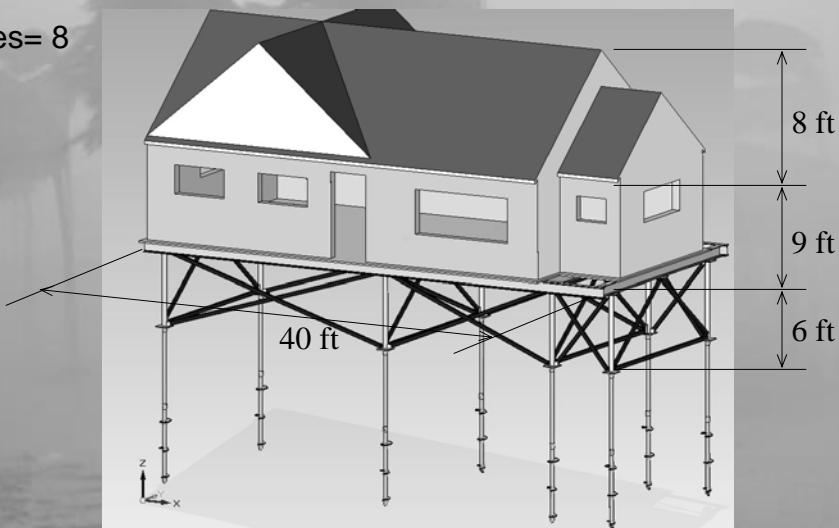


#### Wind Parameters:

Mean Rf Ht= 19 ft

No. Piles= 8

## Example Calculations



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Wind Parameters:

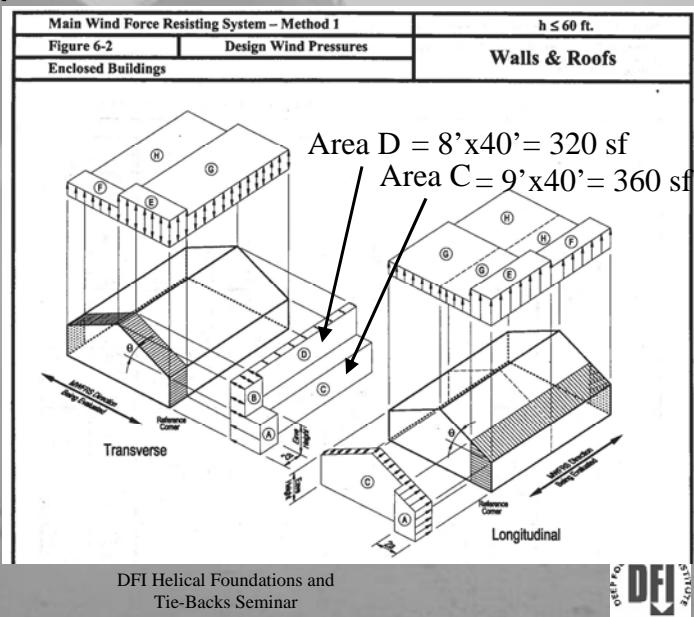
Design Wind Pressure, (IBC 2006)

Mean Rf Ht= 19 ft

No. Piles= 8

Area D = 320 sf

Area C = 360 sf



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Wind Parameters:

Mean Rf Ht= 19 ft

No. Piles= 8

Area D = 320 sf

Area C = 360 sf

Exposure=D

## Exposure Definitions

- Exposure B – Urban & Dense Suburban
- Exposure C – Open Terrain
- Exposure D – Shoreline, Flats, Lakes

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Wind Parameters:

Mean Rf Ht= 19 ft

No. Piles= 8

Area D = 320 sf

Area C = 360 sf

Exposure=D

$\lambda = 1.55$

Adjustment Factors, (IBC 2006)

Mean roof height (ft)	Exposure		
	B	C	D
15	1.00	1.21	1.47
20	1.00	1.29	1.55
25	1.00	1.35	1.61
30	1.00	1.40	1.66
35	1.05	1.45	1.70
40	1.09	1.49	1.74
45	1.12	1.53	1.78
50	1.16	1.56	1.81
55	1.19	1.59	1.84
60	1.22	1.62	1.87

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Wind Parameters:

Mean Rf Ht= 19 ft

No. Piles= 8

Area D = 320 sf

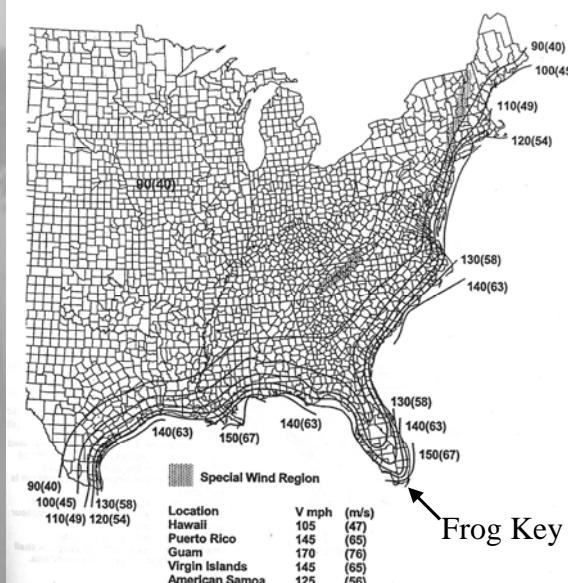
Area C = 360 sf

Exposure=D

$\lambda = 1.55$

3s Gust=150 mph

Basic Wind Speed, 3s Gust (IBC 2006)



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Wind Parameters:

Mean Rf Ht= 19 ft

No. Piles= 8

Area D = 320 sf

Area C = 360 sf

Exposure=D

$\lambda = 1.55$

3s Gust=150 mph

$p_{S30}$ , C= 31.9 psf

$p_{S30}$ , D= 22.0 psf

Design Wind Pressures, (IBC 2006)

Main Wind Force Resisting System – Method 1			
Figure 6-2 (cont'd)		Design Wind Pressures	
Enclosed Buildings			
Simplified Design Wind Pressure , $p_{S30}$ (psf) (Ex)			
Basic Wind Speed (mph)	Roof Angle (degrees)	Load Case	Zone
			V
			A B C D E
<b>140</b>	0 to 5°	1	31.1 -16.1 24.6 -9.6 -37.3
	10°	1	35.1 -14.5 23.3 -4.5 -37.3
	15°	1	39.0 -12.9 26.0 -1.4 -37.3
	20°	1	43.0 -11.4 28.7 -6.3 -37.3
	25°	1	39.0 6.3 28.2 6.4 -17.3
		2	— — — — -6.6
<b>150</b>	30 to 45	1	35.0 23.9 27.8 19.1 2.7
		2	35.0 23.9 27.8 19.1 13.4
	0 to 5°	1	35.7 -18.5 23.7 -11.0 -42.9
	10°	1	40.2 -16.7 26.8 -9.7 -42.9
	15°	1	44.8 -14.9 29.8 -8.5 -42.9
	20°	1	49.4 -13.0 32.9 -7.2 -42.9
	25°	1	44.8 7.2 32.4 7.4 -19.9
		2	— — — — -7.5
	30 to 45	1	49.1 27.4 31.9 22.0 3.1
		2	40.1 27.4 31.9 22.0 15.4

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Wind Parameters:

Mean Rf Ht= 19 ft

No. Piles= 8

Area D = 320 sf

Area C = 360 sf

Exposure=D

$\lambda = 1.55$

3s Gust=150 mph

$p_{S30}$ , C= 31.9 psf

$p_{S30}$ , D= 22.0 psf

## Simplified Wind Loads

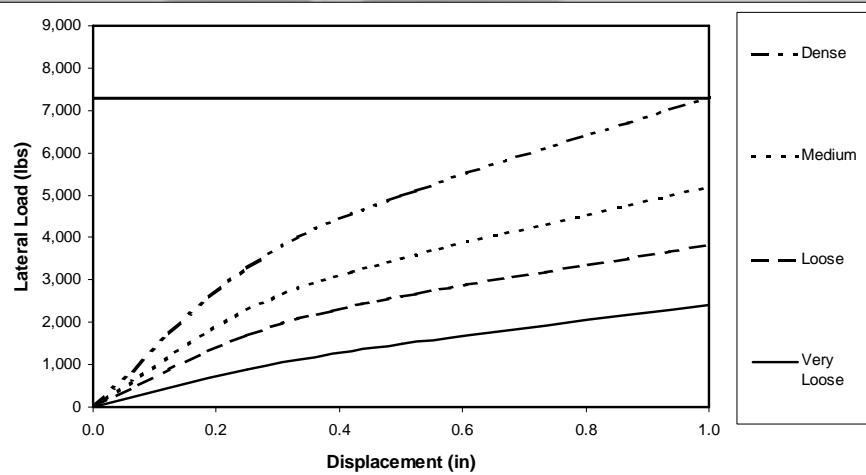
- Design Wind Pressure,  $P_s$ 
  - $P_s = \lambda | p_{S30} |$
  - $P_{sD} = (1.55)(1.0)(31.9) = 49 \text{ psf}$
  - $P_{sC} = (1.55)(1.0)(22.0) = 34 \text{ psf}$
  - $W = (49)(360)+(34)(320)=28 \text{ kips}$
  - $W_{\text{pile}} = 28/8 \text{ piles} = 3.6 \text{ kips/pile}$

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## Lateral Resistance Sand Soils



Capacity/Pile = 7,300/2 = 3.7 kips >3.6 kips, okay!

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## Conclusions

- Round-Shaft Helical Piles Have Small but Significant Lateral Load Resistance
- Steel Truss Assembly can be Used to Transfer Shear to Helical Piles without Concrete
- Field Tests Match Lateral Load Predictions in Dense Soils

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# Questions?

Hurricane Dennis  
Key West, Florida  
July 9th 2005



[UltimateChase.com](http://UltimateChase.com)

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