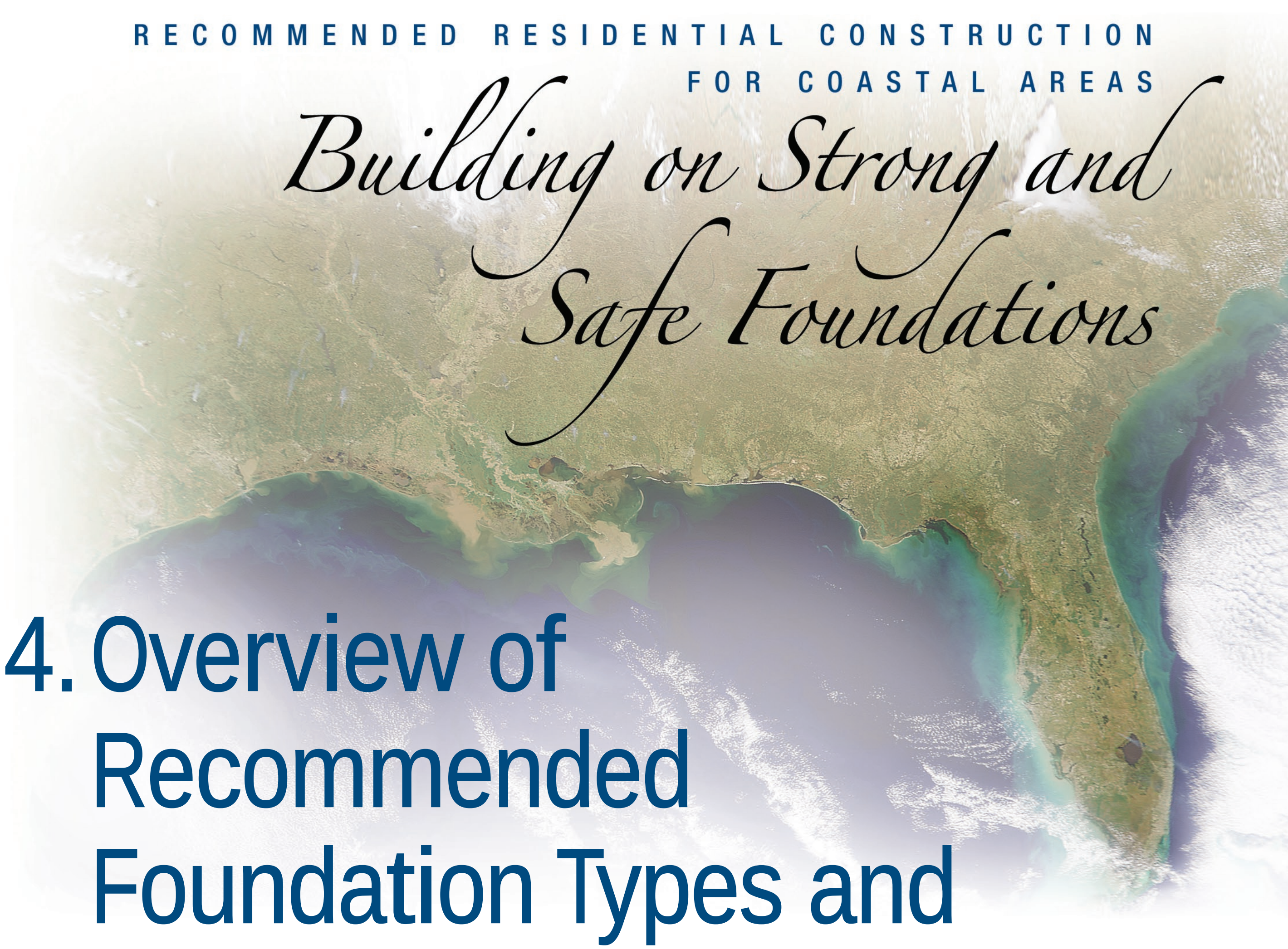
RECOMMENDED RESIDENTIAL CONSTRUCTION
FOR COASTAL AREAS

Building on Strong and
Safe Foundations



4. Overview of Recommended Foundation Types and Construction for Coastal Areas

Chapters 1 through 3 discussed foundation design loads and calculations and how these issues can be influenced by coastal natural hazards. This chapter will tie all of these issues together with a discussion of foundation types and methods of constructing a foundation for a residential structure.

4.1 Critical Factors Affecting Foundation Design

Foundation construction types are dependent upon the following critical factors:

- Design wind speed
- Elevation height required by the BFE and local ordinances
- Flood zone
- Soil parameters

Soil parameters, like bearing capacities, shear coefficients, and subgrade moduli, are important in designing efficient and effective foundations. But, for the purpose of creating the standardized foundation concepts for use in a variety of sites, some soil parameters have been assumed (as in the case of bearing capacity for shallow foundations) and others have been stipulated (as those required to produce specific performance – as in the case for deep driven piles). Assumptions used in developing the foundations are listed in Appendix C, where stipulations on pile capacity are also listed in the individual drawings.

4.1.1 Wind Speed

The basic wind speed determines the wind velocity used in establishing wind loads for a building. It can also have a significant influence on the size and strength of foundations that support homes. Contemporary codes and standards like the IRC, IBC, and ASCE 7 specify basic wind speeds as 3-second gust wind speeds. Earlier versions of codes and standards specified wind speeds with different averaging periods. One example is the fastest mile wind speed that was specified in the 1988 (and earlier) versions of ASCE 7 and in pre-2000 versions of most model building codes.

The wind speed map shown in Figure 3-1 illustrates that the basic (3-second gust) wind speeds along most of the Gulf of Mexico, the Atlantic coast, and coastal Alaska range between 120 and 150 mph. The basic wind speed for most of the Pacific coast is 85 mph. Several areas in the Pacific Northwest are designated as special wind regions and wind speeds are dictated locally. The design wind speeds for many of the U.S. territories and protectorates are tabulated in ASCE 7.

To determine forces on the building and foundation, the wind speed is critical. Wind speed creates wind pressures that act upon the building. These pressures are proportional to the square of the wind speed, so a doubling of the wind speed increases the wind pressure by a factor of four. The pressure applied to an area of the building will develop forces that must be resisted. To transfer these forces from the building to the foundation, properly designed load paths are required. For the foundation to be properly designed, all forces including uplift, compression, and lateral must be taken into account.

Although wind loads are important in the design of a building, in coastal areas flood loads often have a much greater effect on the design of the foundation itself.

4.1.2 Elevation

The required height of the foundation depends on three factors: the DFE, the site elevation, and the flood zone. The flood zone dictates whether the lowest habitable finished floor must be placed at the DFE or, in the case of homes in the V zone, the bottom of the lowest horizontal member must be placed at the DFE. Figure 4-1 illustrates how the BFE, freeboard, erosion, and the ground elevation determine the foundation height required. While not required by the NFIP, V zone criteria are recommended for Coastal A zones. Stated mathematically:

$$H = DFE - G + Erosion$$

or

$$H = BFE - G + Erosion + Freeboard$$

Where

H = Required foundation height (in ft)
DFE = Design Flood Elevation
BFE = Base Flood Elevation
G = Non-eroded ground elevation
Erosion = Short-term plus long-term erosion
Freeboard = 2009 IRC required in SFHAs, locally adopted or owner desired freeboard

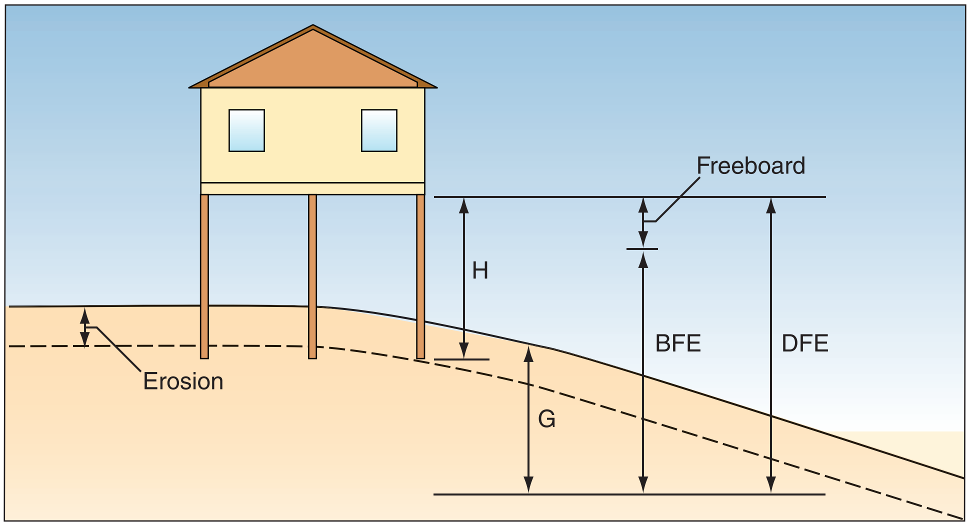


Figure 4-1.
The BFE, freeboard, erosion, and ground elevation determine the foundation height required.

The height to which a home should be elevated is one of the key factors in determining which pre-engineered foundation to use. Elevation height is dependent upon several factors, including the BFE, local ordinances requiring freeboard, and the desire of the homeowner to elevate the lowest horizontal structural member above the BFE (see also Chapter 2). This manual provides designs for closed foundations up to 8 feet above ground level and open foundations up to 15 feet above ground level. Custom designs can be developed for open and closed foundations to position the homes above those elevation levels. Foundations for homes that need to be elevated higher than 15 feet should be designed by a licensed professional engineer.

4.1.3 Construction Materials

The use of flood-resistant materials below the BFE is also covered in FEMA NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program* and FEMA 499, Fact Sheet No. 8 (see Appendix F). This manual will cover the materials used in masonry and concrete foundation construction, and field preservative treatment for wood.

4.1.3.1 Masonry Foundation Construction

The combination of high winds, moisture, and salt-laden air creates a damaging recipe for masonry construction. All three can penetrate the tiniest cracks or openings in the masonry joints. This can corrode reinforcement, weaken the bond between the mortar and the brick, and create fissures in the mortar. Moisture resistance is highly influenced by the quality of the materials and the workmanship.

4.1.3.2 Concrete Foundation Construction

Cast-in-place concrete elements in coastal environments should be constructed with 3 inches or more of concrete cover over the reinforcing bars. The concrete cover physically protects the reinforcing bars from corrosion. However, if salt water penetrates the concrete cover and reaches the reinforcing steel, the concrete alkalinity is reduced by the salt chloride, thereby corroding the steel. As the corrosion forms, it expands and cracks the concrete, allowing the additional entry of water and further corrosion. Eventually, this process weakens the concrete structural element and its load carrying capacity.

Alternatively, epoxy-coated reinforcing steel can be used if properly handled, stored, and placed. Epoxy-coated steel, however, requires more sophisticated construction techniques and more highly trained contractors than are usually involved with residential construction.

Concrete mix used in coastal areas must be designed for durability. The first step in this process is to start with the mix design. The American Concrete Institute (ACI) 318 manual recommends that a maximum water-cement ratio by weight of 0.40 and a minimum compressive strength of 4,000 pounds per square inch (psi) be used for concrete used in coastal environments. Since the amount of water in a concrete mix largely determines the amount that concrete will shrink and promote unwanted cracks, the water-cement ratio of the concrete mix is a critical parameter in promoting concrete durability. Adding more water to the mix to improve the workability increases the potential for cracking in the concrete and can severely affect its durability.

Another way to improve the durability of a concrete mix is with ideal mix proportions. Concrete mixes typically consist of a mixture of sand, aggregate, and cement. How these elements are proportioned is as critical as the water-cement ratio. The sand should be clean and free of contaminants. The aggregate should be washed and graded. The type of aggregate is also very important.

Recent research has shown that certain types of gravel do not promote a tight bond with the paste. The builder or contractor should consult expert advice prior to specifying the concrete mix.

Addition of admixtures such as pozzolans (fly ash) is recommended for concrete construction along the coast. Fly ash when introduced in concrete mix has benefits such as better workability and increased resistance to sulfates and chlorates, thus reducing corrosion from attacking the steel reinforcing.

4.1.3.3 Field Preservative Treatment for Wood Members

In order to properly connect the pile foundation to the floor framing system, making field cuts, notches, and boring holes are some of the activities associated with construction. Since pressure-preservative-treated piles, timbers, and lumber are used for many purposes in coastal construction, the interior, untreated parts of the wood are exposed to possible decay and infestation. Although treatments applied in the field are much less effective than factory treatments, the potential for decay can be minimized. The American Wood Preservers' Association (AWPA) *AWPA M4-08 Standard for the Care of Preservative-Treated Wood Products* (AWPA 2008) describes field treatment procedures and field cutting restrictions for poles, piles, and sawn lumber.

Field application of preservatives should always be done in accordance with instructions on the label. When detailed instructions are not provided, dip soaking for at least 3 minutes can be considered effective for field applications. When this is impractical, treatment may be done by thoroughly brushing or spraying the exposed area. It should be noted that the material is more absorptive at the end of a member, or end grains, than it is for the sides or side grains. To safeguard against decay in bored holes, the holes should be poured full of preservative. If the hole passes through a check (such as a shrinkage crack caused by drying), it will be necessary to brush the hole; otherwise, the preservative would run into the check instead of saturating the hole.

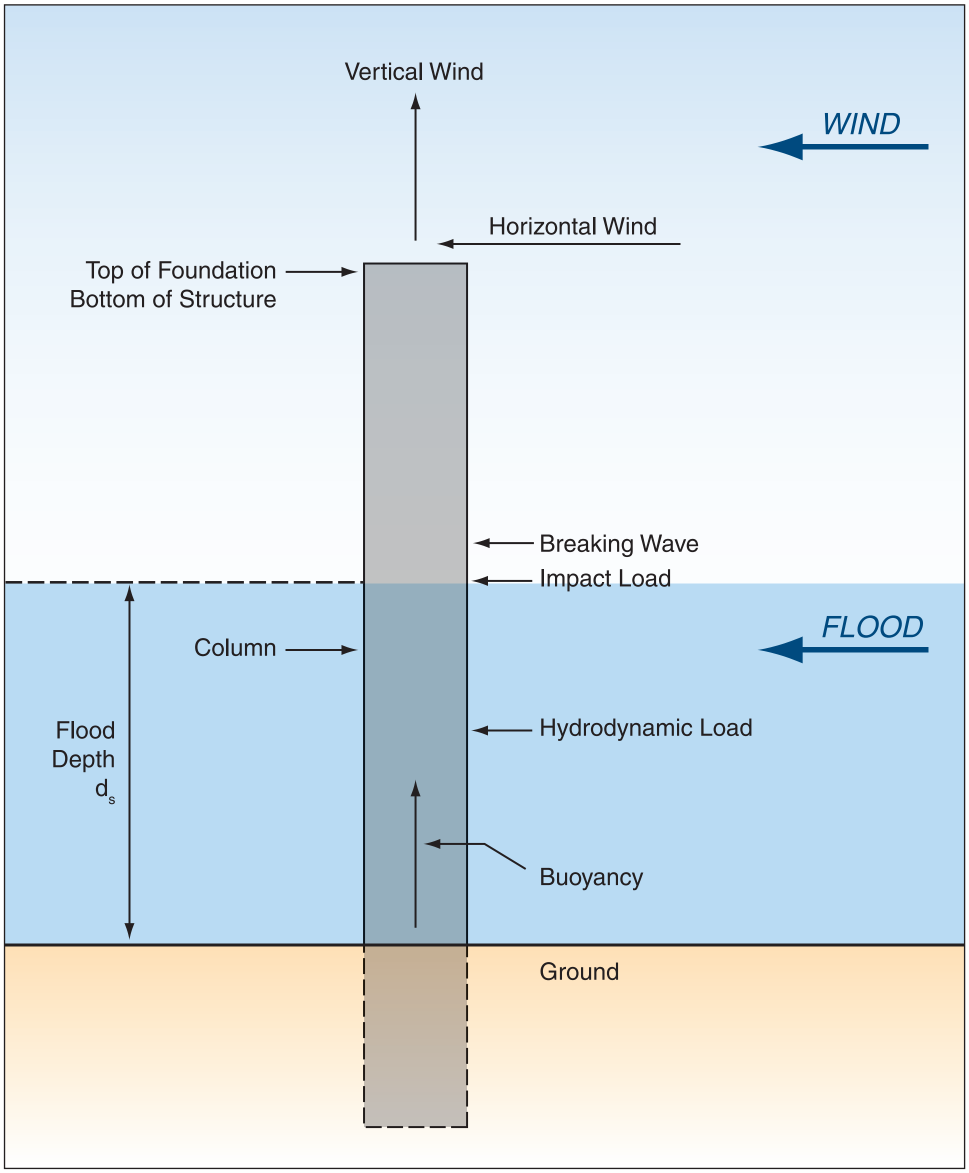
Waterborne arsenicals, pentachlorophenol, and creosote are unacceptable for field applications. Copper napthenate is the most widely used field treatment. Its deep green color may be objectionable, but the wood can be painted with alkyd paints in dark colors after extended drying. Zinc napthenate is a clear alternative to copper napthenate. However, it is not quite as effective in preventing insect infestation, and it should not be painted with latex paints. Tributyltin oxide (TBTO) is available, but should not be used in or near marine environments, because the leachates are toxic to aquatic organisms. Sodium borate is also available, but it does not readily penetrate dry wood and it rapidly leaches out when water is present. Therefore, sodium borate is not recommended.

4.1.4 Foundation Design Loads

To provide flexibility in the home designs, tension connections have been specified between the tops of all wood piles and the grade beams. Depending on the location of shear walls, shear wall openings, and the orientation of floor and roof framing, some wood piles may not experience tension forces. Design professionals can analyze the elevated structure to identify compression only piles to reduce construction costs. For foundation design and example calculations, see Appendix D.

Figure 4-2 illustrates design loads acting on a column. The reactions at the base of the elevated structure used in most of the foundation designs are presented in Tables 4-1a (one-story) and 4-1b (two-story). These reactions are the controlling forces for the range of building weights and dimensions listed in Appendix A and shown in Figure 2 of the Introduction. Design reactions have been included for the various design wind speeds and various building elevations above exterior grade. ASCE 7-05 load combination 4 ($D + 0.75L + 0.75L_r$) controls for gravity loading and load combination 7 controls for uplift and lateral loads. Load combination 7 is $0.6D + W + 0.75F_a$ in non-Coastal A zones and $0.6D + W + 1.5F_a$ in Coastal A and V zones. Refer to Section 3.8 for the list of flood load combinations.

Figure 4-2.
Design loads acting on a column.



Loads on the foundation elements themselves are more difficult to tabulate because they depend on the foundation style (open or enclosed), foundation dimensions, and foundation height. Table 4-2 provides reactions for the 18-inch square columns used in most of the open foundation designs.

Table 4-1a. Design Perimeter Wall Reactions (lb/lf) for One-Story Elevated Homes (Note: Reactions are taken at the base of the elevated home/top of the foundation element.)

V	120 mph		130 mph		140 mph		150 mph		(All V)
H	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Gravity
5 ft	770	-175	903	-259	1,048	-350	1,203	-448	1,172
6 ft	770	-175	903	-259	1,048	-350	1,203	-448	1,172
7 ft	770	-175	903	-259	1,048	-350	1,203	-448	1,172
8 ft	804	-202	944	-291	1,095	-388	1,257	-490	1,172
10 ft	804	-202	944	-291	1,095	-388	1,257	-490	1,172
12 ft	804	-202	944	-291	1,095	-388	1,257	-490	1,172
14 ft	832	-224	977	-317	1,133	-417	1,300	-525	1,172
15 ft	843	-226	989	-319	1,147	-419	1,317	-527	1,172

lb = pound
lf = linear foot
V = wind speed

H = height of foundation above grade
Horiz = horizontal
Vert = vertical

Table 4-1b. Design Perimeter Wall Reactions (lb/lf) for Two-Story Elevated Homes (Note: Reactions are taken at the base of the elevated home/top of the foundation element.)

V	120 mph		130 mph		140 mph		150 mph		(All V)
H	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Gravity
5 ft	1,149	-145	1,348	-255	1,564	-374	1,795	-502	1,608
6 ft	1,149	-145	1,348	-255	1,564	-374	1,795	-502	1,608
7 ft	1,149	-145	1,348	-255	1,564	-374	1,795	-502	1,608
8 ft	1,182	-168	1,387	-282	1,609	-406	1,847	-539	1,608
10 ft	1,191	-171	1,397	-286	1,629	-410	1,860	-543	1,608
12 ft	1,191	-171	1,397	-286	1,620	-410	1,860	-543	1,608
14 ft	1,191	-171	1,397	-286	1,620	-410	1,860	-543	1,608
15 ft	1,210	-175	1,420	-291	1,647	-416	1,890	-550	1,608

b = pound
lf = linear foot
V = wind speed

H = height of foundation above grade
Horiz = horizontal
Vert = vertical

Table 4-2. Flood Forces (in pounds) on an 18-Inch Square Column

Flood Depth	Hydrodynamic	Breaking Wave	Impact	Buoyancy
5 ft	1,000	684	3,165	465
6 ft	1,440	985	3,476	577
7 ft	1,960	1,340	3,745	650

Table 4-2. Flood Forces (in pounds) on an 18-Inch Square Column (continued)

Flood Depth	Hydrodynamic	Breaking Wave	Impact	Buoyancy
8 ft	2,560	1,750	4,004	743
10 ft	4,001	2,735	4,476	939
12 ft	5,761	3,938	4,903	1,115
14 ft	7,841	5,360	5,296	1,300
15 ft	9,002	6,155	5,482	1,394

4.1.5 Foundation Design Loads and Analyses

Load analyses used to develop Case H foundations are similar to the analyses completed for the original FEMA 550 designs. Live loads used were those specified by the IRC and the original and augmented foundations were developed to support a range of dead loads. Wind and flood loads were calculated per ASCE 7, *Minimum Design Loads for Buildings and Other Structures* (the Case H design loads were calculated using ASCE 7-05; loads used in the original designs were calulated using ASCE 7-02, which are consistent with the 2005 edition). Design assumptions are listed in Appendix C.

Some noteworthy differences exist. Wind loads used in the original FEMA 550 designs were the worst case loads for a home that varied in width from 24 feet to 42 feet and in roof slope from 3:12 to 12:12. The foundation reactions for the original designs are listed in Table 4-1b. In the Case H designs, separate wind loads were determined based on the number of stories (one or two) and the building width (14 feet for the 3-bay designs, 28 feet for the 6-bay designs, and 42 feet for the 9-bay designs). The more precise matching of wind loads to building widths and heights provide greater design efficiencies.

Wind loads used to develop the Case H foundations are listed in Table 4-3.

Table 4-3. Wind Reactions Used to Develop Case H Foundations

	Two-Story								
	3-Bay			6-Bay			9-Bay		
	ww (p/lf)	lw (p/lf)	lat (p/lf)	ww (p/lf)	lw (p/lf)	lat (p/lf)	ww (p/lf)	lw (p/lf)	lat (p/lf)
120 mph	-710	320	420	-640	-50	510	-730	-270	610
130 mph	-840	380	490	-750	-60	600	-860	-310	710
140 mph	-970	440	570	-870	-70	700	-1,000	-360	830
150 mph	-1,100	500	650	-1,000	-80	800	-1,140	-410	950

Table 4-3. Wind Reactions Used to Develop Case H Foundations (continued)

	One-Story								
	3-Bay			6-Bay			9-Bay		
	ww (p/lf)	lw (p/lf)	lat (p/lf)	ww (p/lf)	lw (p/lf)	lat (p/lf)	ww (p/lf)	lw (p/lf)	lat (p/lf)
120 mph	-340	-20	240	-440	-200	320	-580	-340	410
130 mph	-400	-20	280	-510	-230	380	-680	-400	480
140 mph	-470	-30	320	-600	-270	440	-790	-460	560
150 mph	-540	-30	370	-690	-310	500	-900	-530	640

ww = vertical forces on windward edge of foundation

lw = vertical forces on leeward edge of foundation

lat = horizontal forces on windward and leeward edges of foundation

1. (+) loads act upward; (-) pressures act downward.
2. Lateral loads are applied to both windward and leeward foundation elements.

To account for shear panel reactions from segmented shear walls, the analyses of foundations supporting one-story homes included 6.72 kip quarter span point loads for the 3-bay design (point loads were applied at mid-span for the 6- and 9-bay models, Figure 4-3). The loads correspond to 10-foot tall wood framed shear panels constructed with 7/16-inch blocked wood structural panels fastened with 8d common nails 6 inches on center (o.c.). Foundations supporting two-story homes were analyzed with 13.44 kip shear panel reactions or twice that of the one-story home. The foundations will also support homes constructed with perforated shear walls.

Another difference in design methodology was required due to the nature of structural frames. In the original designs, the concrete columns were considered statically determinant and analyzed as such. The structural frames created by the concrete grade beams, concrete columns, and elevated beams, however, are not statically determinant and computer modeling was warranted. To analyze the frame action developed by those structural elements, computer models using RISA© structural software were created. Design loads were applied to the frames and critical shears and moments were tabulated for the grade beams, columns, and elevated beams. Critical axial forces were also tabulated for the columns.

Tables 4-4 through 4-9 summarize the critical shears, moments, and axial loads of the computer models used to develop the Case H foundations.

Figure 4-3.
Shear panel reactions for the 3- and 6-bay models. Reactions for the 9-bay model were similar to those of the 6-bay.

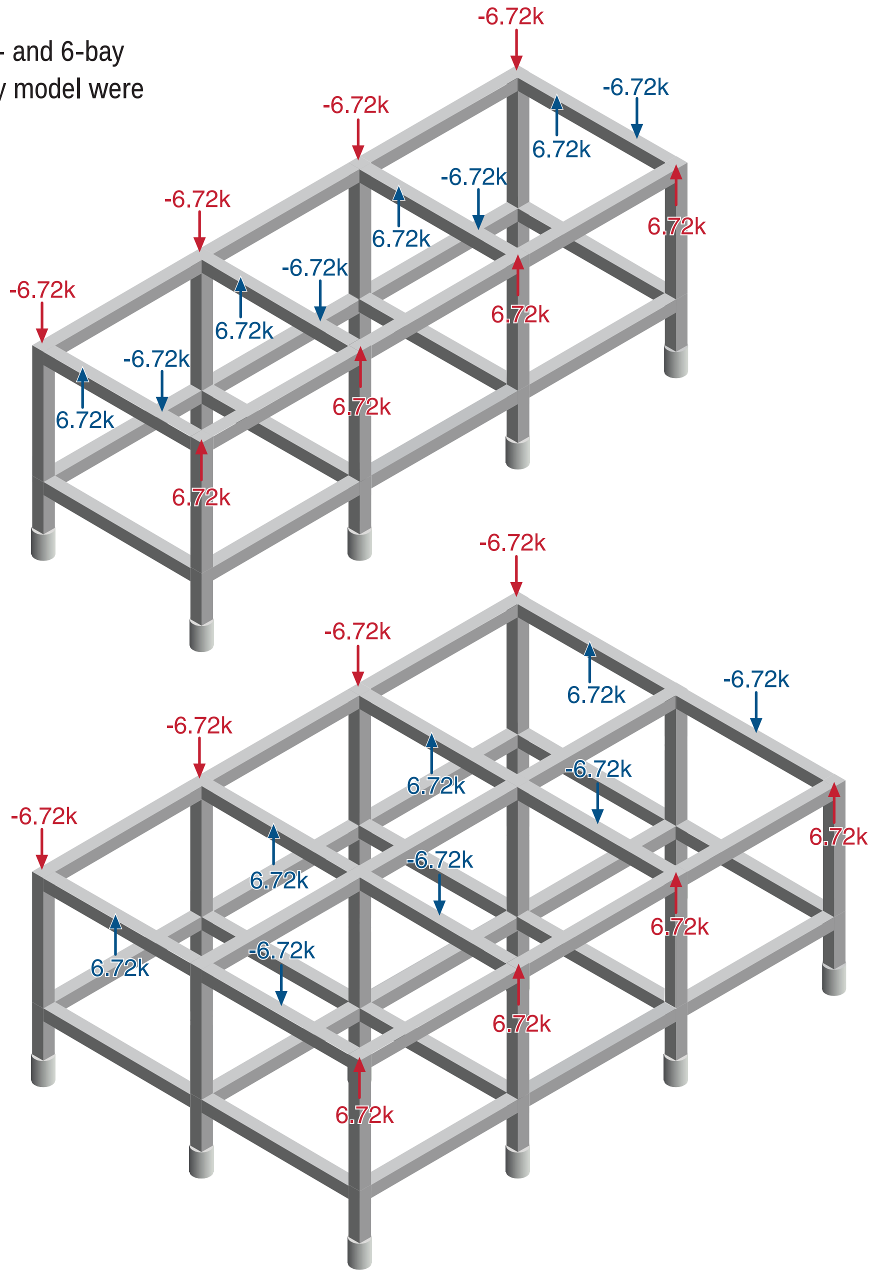


Table 4-4. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 10-Foot Tall 3-Bay Foundations

10-Foot Foundation	3-Bay One-Story				3-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Column Moment +	24	25	27	30	33	38	44	51
Column Moment -	37	40	43	47	51	57	63	69
Column Shear Bottom	9	9	10	10	11	12	13	14
Column Shear Top	5	6	6	8	8	9	11	12

Table 4-4. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 10-Foot Tall 3-Bay Foundations (continued)

10-Foot Foundation	3-Bay One-Story				3-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Axial Maximum	24	24	24	25	46	48	49	50
Axial Minimum	8	8	7	7	1.6	1.2	0.5	0.3
Elevated Beam Moment +	22	24	26	29	39	43	46	47
Elevated Beam Moment -	21	23	25	27	41	44	48	51
Elevated Beam Shear at Column	3	3	3	3	4	4	3	3
Elevated Beam Shear at Mid-Span	7	7	8	8	13	14	15	15
Grade Beam Moment +	30	30	30	31	41	42	44	46
Grade Beam Moment -	18	18	19	20	26	28	30	32
Grade Beam Shear at Column	9	9	9	9	10	10	10	10
Grade Beam Shear at Mid-Span	4	4	4	4	5	5	6	6

1. (+) loads act upward; (-) pressures act downward.

Table 4-5. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 15-Foot Tall 3-Bay Foundations

15-Foot Foundation	3-Bay One-Story				3-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Column Moment +	53	57	62	67	73	81	90	98
Column Moment -	79	84	88	95	104	112	122	132
Column Shear Bottom	13	13	14	15	15	17	18	19
Column Shear Top	6	6	7	8	9	10	11	12
Axial Maximum	27	27	27	28	46	48	50	53
Axial Minimum	7	7	6	6	12	1	-0.3	-1.6
Elevated Beam Moment +	51	55	59	65	67	79	87	95
Elevated Beam Moment -	39	46	50	55	63	68	78	86
Elevated Beam Shear at Column	4	5	5	6	3	4	5	6
Elevated Beam Shear at Mid-Span	11	12	13	13	19	20	21	22
Grade Beam Moment +	30	30	30	29	36	37	39	41
Grade Beam Moment -	21	21	21	21	26	27	29	31

Table 4-5. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 15-Foot Tall 3-Bay Foundations (continued)

15-Foot Foundation	3-Bay One-Story				3-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Grade Beam Shear at Column	9	9	9	9	10	10	9	10
Grade Beam Shear at Mid-Span	4	4	4	4	5	5	4	5

1. (+) loads act upward; (-) pressures act downward.

Table 4-6. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 10-Foot Tall 6-Bay Foundations

10-Foot Foundation	6-Bay One-Story				6-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Column Moment +	56	59	62	65	77	84	90	97
Column Moment -	74	78	81	85	69	75	81	88
Column Shear Bottom	19	20	21	21	17	18	19	20
Column Shear Top	8	9	10	11	14	15	17	19
Axial Maximum	32	32	30	30	47	47	46	46
Axial Minimum	8	8	7	6	10	9	9	8
Elevated Beam Moment +	29	31	32	33	42	44	46	48
Elevated Beam Moment -	23	23	23	23	42	42	43	43
Elevated Beam Shear at Column	9	9	9	9	14	14	14	15
Elevated Beam Shear at Mid-Span	3	3	3	3	7	7	7	8
Grade Beam Moment +	71	73	77	80	60	64	69	74
Grade Beam Moment -	53	75	79	83	55	61	67	73
Grade Beam Shear at Column	13	13	14	14	11	12	12	14
Grade Beam Shear at Mid-Span	10	11	11	11	8	9	10	11

1. (+) loads act upward; (-) pressures act downward.

Table 4-7. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 15-Foot Tall 6-Bay Foundations

15 Foot Foundation	6-Bay One-Story				6-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Column Moment +	81	87	92	98	118	127	137	140
Column Moment -	100	105	111	118	129	139	150	157
Column Shear Bottom	15	16	17	18	20	21	22	24

Table 4-7. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 15-Foot Tall 6-Bay Foundations (continued)

15 Foot Foundation	6-Bay One-Story				6-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Column Shear Top	9	10	11	11	13	14	16	18
Axial Maximum	37	37	32	33	48	48	48	45
Axial Minimum	-1	-2	-4	-5	1	-1	-1	-1
Elevated Beam Moment +	43	46	49	52	62	66	71	75
Elevated Beam Moment -	23	22	24	27	44	44	44	41
Elevated Beam Shear at Column	11	11	12	12	16	16	17	18
Elevated Beam Shear at Mid-Span	2	2	1	2	4	5	3	3
Grade Beam Moment +	99	104	109	114	119	127	136	140
Grade Beam Moment -	107	114	121	129	128	138	150	155
Grade Beam Shear at Column	19	20	21	21	22	23	20	19
Grade Beam Shear at Mid-Span	15	16	16	18	18	19	18	15

1. (+) loads act upward; (-) pressures act downward.

Table 4-8. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 10-Foot Tall 9-Bay Foundations

10-Foot Foundation	9-Bay One-Story				9-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Column Moment +	21	23	26	29	24	28	32	36
Column Moment -	40	43	47	50	52	56	61	63
Column Shear Bottom	9	9	10	10	10	11	12	13
Column Shear Top	4	5	6	7	6	7	9	10
Axial Maximum	32				47			
Axial Minimum	8				10			
Elevated Beam Moment +	29	29	29	29	47	47	47	47
Elevated Beam Moment -	15	15	15	15	25	25	25	25
Elevated Beam Shear at Column	11	11	11	11	18	18	18	18
Elevated Beam Shear at Mid-Span	12	12	12	12	20	20	20	20
Grade Beam Moment +	45	48	51	54	55	58	63	68
Grade Beam Moment -	44	47	50	54	56	60	66	71

Table 4-8. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 10-Foot Tall 9-Bay Foundations (continued)

10-Foot Foundation	9-Bay One-Story				9-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Grade Beam Shear at Column	9	10	10	10	10	11	12	13
Grade Beam Shear at Mid-Span	7	7	8	7	7	8	8	9

1. (+) loads act upward; (-) pressures act downward.

Table 4-9. Design Moments (K-ft), Axial Loads (in kips), and Shears (in kips) for 15-Foot Tall 9-Bay Foundations

15 Foot Foundation	9-Bay One-Story				9-Bay Two-Story			
	120 mph	130 mph	140 mph	150 mph	120 mph	130 mph	140 mph	150 mph
Column Moment +	49	54	59	98	51	65	73	81
Column Moment -	80	86	92	118	100	106	115	124
Column Shear Bottom	12	13	14	18	14	15	16	17
Column Shear Top	6	6	7	11	7	8	10	11
Axial Maximum	34	39	34	34	49	49	49	49
Axial Minimum	6	6	6	6	9	8	8	8
Elevated Beam Moment +	29	29	29	29	48	48	48	48
Elevated Beam Moment -	16	16	16	13	26	26	26	26
Elevated Beam Shear at Column	15	12	12	12	20	20	20	20
Elevated Beam Shear at Mid-Span	2	1	1	1	2	2	2	2
Grade Beam Moment +	95	100	105	114	111	117	125	133
Grade Beam Moment -	103	109	116	128	123	132	141	151
Grade Beam Shear at Column	19	19	20	22	21	22	23	25
Grade Beam Shear at Mid-Span	14	15	16	18	17	18	19	21

1. (+) loads act upward; (-) pressures act downward.

4.2 Recommended Foundation Types for Coastal Areas

Table 4-10 provides six open (deep and shallow) foundation types and two closed foundations discussed in this manual. Appendix A provides the foundation design drawings for the cases specified.

Table 4-10. Recommended Foundation Types Based on Zone

Foundation		Case	V Zones	A Zones in Coastal Areas	
				Coastal A Zone	A Zone
Open Foundation (deep)	Braced timber pile	A	4	4	4
	Steel pipe pile with concrete column and grade beam	B	4	4	4
	Timber pile with concrete column and grade beam	C	4	4	4
	Timber pile with concrete grade and elevated beams and concrete columns	H	4	4	4
Open Foundation (shallow)	Concrete column and grade beam	D	NR	4	4
	Concrete column and grade beam with integral slab	G	NR	4	4
Closed Foundation (shallow)	Reinforced masonry – crawlspace	E	8	NR	4
	Reinforced masonry – stem wall	F	8	NR	4

4 = Acceptable

NR = Not Recommended

8 = Not Permitted

The foundation designs contained in this manual are based on soils having a bearing capacity of 1,500 pounds per square foot (psf). The 1,500-psf bearing capacity value corresponds to the presumptive value contained in Section 1806 of the 2009 IBC. The presumptive bearing capacity is for clay, sandy clay, silty clay, clayey silt, and sandy silt (CL, ML, MH, and CH soils).

The size of the perimeter footings and grade beams are generally not controlled by bearing capacity (uplift and lateral loads typically control footing size and grade beam dimensions). Refining the designs for soils with greater bearing capacities may not significantly reduce construction costs. However, the size of the interior pad footings for the crawlspace foundation (Table 4-10, Case E) depends greatly on the soil's bearing capacity. Design refinements can reduce footing sizes in areas where soils have greater bearing capacities. The following discussion of the foundation designs listed in Table 4-10 is also presented in Appendix A. Figures 4-4 through 4-10 are based on Appendix A.

4.2.1 Open/Deep Foundation: Timber Pile (Case A)

This pre-engineered, timber pile foundation uses conventional, tapered, treated piles and steel rod bracing to support the elevated structure. No concrete, masonry, or reinforcing steel is needed (see Figure 4-4). Often called a "stilt" foundation, the driven timber pile system is