FEMA 550

Recommended Residential Construction for the Gulf Coast

By David Low, P.E.

Hurricane Katrina destroyed thousands of homes and created a need for wind and flood resistant residential foundation designs. FEMA 550 *Recommended Residential Construction for the Gulf Coast* was developed to help satisfy that need. FEMA 550 contains prescriptive foundation designs suitable for coastal and near-coastal areas, and guidance to help design professionals develop their own flood and wind resistant foundations designs.

The Carnage

As the Gulf of Mexico pounded structural engineer Scott Sundberg's rented house, Scott and his wife Caroline ran toward the second floor to race from the advancing floodwaters. After waves crashed through their rear wall, the panicked couple swam through a broken window and escaped. Once outside, they struggled to swim to their small sailboat that had just floated off its trailer. Moments later, the home they lived in while building their dream house was gone – washed from its foundation by the seas churned up by Katrina's hurricane force winds.

House washed away from its foundation. Only the sill plates remained.

For five hours, they clung to their overturned sailboat. Their little nineteen foot boat, that had previously provided hours of pleasure in the Gulf of Mexico, became their lifeline. Fortunately the couple survived.

Scott and Caroline's story was likely repeated thousands of times over. Katrina's wrath extended well into areas thought to be safe from flooding. Along miles of the coast, homes built within 1,500 feet of the Gulf of Mexico not only flooded but were reduced to rubble. In Mississippi alone, the Red Cross estimated Katrina destroyed nearly 70,000 homes and severely damaged nearly 65,000 more. In Mississippi and Louisiana, over 1,700 people perished. Floods destroyed the vast majority of homes. While at landfall Katrina only packed wind speeds of a Category 3 storm, it produced storm surge expected from a Cat 5 hurricane – the worst flooding on record. Along the Mississippi coast, storm surge raised the Gulf of Mexico's waters from 17 to 23 feet. Including wave heights, the highest recorded flood level was nearly 35 feet.

Pre-FIRM (Flood Insurance Rate Map) structures are structures that were built before the date of the community's initial FIRM. Many Pre-Firm homes do not meet present elevation requirements but are essentially grandfathered into the program and can be insured through the NFIP (National Flood Insurance Program).

What Happened

Floodwaters from Katrina rushed into coastal communities and reached areas thought to be safe from flooding. Many homes destroyed were outside of the designated Special Flood Hazard Areas (SFHAs).

Most flood ravaged homes were destroyed, due primarily to the fact that they were not elevated high enough. Destroyed homes were often non-elevated older pre-FIRM structures (built below the BFE – or Base Flood Elevation), were located outside of SFHAs (and therefore not required to be elevated), or were elevated to the BFE in areas where Katrina produced floods that exceeded the base flood.

Foundations historically used in the Gulf were no match for Katrina's battering storm surge, breaking waves and flood borne debris particularly in areas where floods exceeded design levels. In coastal Mississippi, many homes were constructed on masonry stem walls (locally called "chain walls") consisting of concrete spread footings, short (typically 3-foot tall or less) masonry walls and floor slabs elevated on backfill. Many stem wall foundations survived, but the homes they once supported were washed away.

"Open" style foundations, better suited for coastal areas, also failed. In coastal Mississippi, most open foundations were constructed with masonry piers placed on discrete concrete pad footings. Three methods of failure were repeatedly observed in those foundations: 1) masonry piers failed when struck by flood-borne debris, by breaking waves or when wind and flood loads imposed

Masonry piers and footings overturned and toppled.

on the elevated structure exceeded the pier strength; 2) the discrete concrete footings that supported the piers were either undermined by scour or erosion, or failed when they could not withstand the overturning moment imposed on them from lateral loads on the elevated home and its foundation; and, 3) floodwaters overstressed the connections between the tops of the piers and the bottom of the elevated home allowing the home to wash off its foundation.

While few and far between, some foundations succeeded. Pilings with sufficient embedment to retain their strength after scour and erosion washed away much of the supporting soils away typically fared well.

Also, homes constructed with properly reinforced concrete columns and grade beams, like the dream home Scott and Caroline Sundberg were building, survived even when 6 feet of floodwater inundated their elevated home.

Connection failures allowed homes to float off their foundations.

Avoiding a Repeat

Katrina's wrath demonstrated that homes along the coast must be built stronger to resist wind loads and higher to avoid flooding.

For over 60 years, building codes and standards have addressed wind forces. The preface to ANSI 58.1-1982 (the precursor to ASCE 7) states wind criteria were first included in the 1945 edition of the A58 standard. Wind provisions are constantly being upgraded as data from wind tunnel tests, post-event assessments and other research become available. The latest major changes to the ASCE 7 wind provisions occurred in

The Sundberg home. Open foundation constructed with reinforced concrete columns and grade beams/ footings. Foundation survived even after the home was inundated with six feet of water and exposed to breaking waves and flood-borne debris.

1995 when, among other changes, 3-second gust wind speeds became the basis for wind load calculations.

Wind provisions have also made their way into prescriptive codes and standards, particularly for residential construction. Prescriptive codes and standards present "how to" methods of complying with performance standards like ASCE 7. The Southern Building Code Congress International's (SBCCI) legacy standard SSTD-10 *Standard for Hurricane Resistant Construction* and the International Code Conference's (ICC) *International Residential Code* are two widely adopted documents that contain prescriptive wind resistant designs. ICC is also developing ICC-600 *Standard for Residential Construction in High Wind Areas* to replace SSTD-10. ICC-600 will include state-of-the-art (ASCE 7-05) wind provisions; the latest edition of SSTD-10 is based on the nearly 20 year old wind provisions of ASCE 7-88. ICC-600 is scheduled to be issued in 2008.

Compared to wind provisions, the flood provisions in model codes and standards are still in their infancy. Flood loads were first included in the 1995 edition of ASCE 7-95, and ASCE 24 *Flood Resistant Design and Construction*, which was first issued in 1998, specifies additional requirements for structures built in Special Flood Hazard Areas. While ASCE standards have made great progress on performance criteria, to a large extent, flood provisions have not yet made their way into prescriptive standards. Without prescriptive designs, building owners must either use design professionals to develop flood-resistant designs or risk having homes that are not adequate to resist flood forces. While commonly involved with commercial buildings, design professional are only rarely involved in designing one and two family homes.

With no meaningful prescriptive flood resistant designs available, homes rebuilt after Katrina's devastation can easily remain vulnerable to flood damage.

Hurricane Katrina's damage to housing and other buildings was unprecedented in the United States. Like the destruction, the scale and extent of the reconstruction is also unprecedented. Given this fact, and the fact that a post-Katrina review of Flood Insurance Rate Maps led to an expansion of the 100-year floodplain and an the increase in Base Flood Elevation (BFE), thousands of rebuilt homes must now be at elevations beyond the previous experience of designers, contractors and communities, and thousands more rebuilt homes will be subject to flood-resistant design requirements for the first time.

The NFIP requires engineering involvement in the high hazard V-Zones where wave heights can exceed 3 feet. The NFIP does not require engineering involvement in other coastal areas where flood damage is often observed.

Compounding this is the fact that, prior to Katrina, many Gulf Coast areas had adopted older building codes, had not strictly enforced the codes they adopted or had adopted no codes at all. While Katrina changed that to some extent (Louisiana and Mississippi have taken steps to adopt newer model codes) the newness of the adopted codes, including their wind and flood design requirements, resulted in many requests for help and guidance from the designers, builders and code officials now responsible for rebuilding.

It was for these reasons that FEMA developed the 550 publication, says John Ingargiola, the Senior Engineer at FEMA responsible for leading the Katrina Mitigation Assessment Team Building Performance Study and for the development of FEMA 550. "We wanted to help reduce the tremendous engineering burden created by the need to rebuild thousands of destroyed homes and provide communities with reliable, prescriptive, pre-engineered foundation solutions complete with cost estimates, plans and guidance for selecting the most appropriate design."

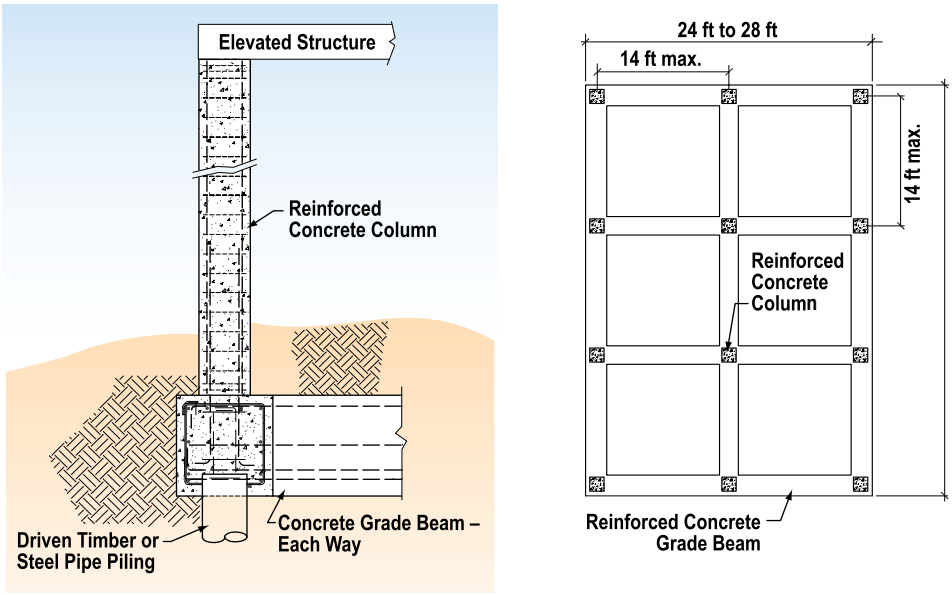
The Designs

FEMA 550 contains seven prescriptive foundation designs for one and two family dwellings for use in coastal and near-coastal areas (V-Zones, Coastal A-Zones and flood zones landward of Coastal A-Zones). Some of the designs are for "open" foundations and some are for "closed" foundations.

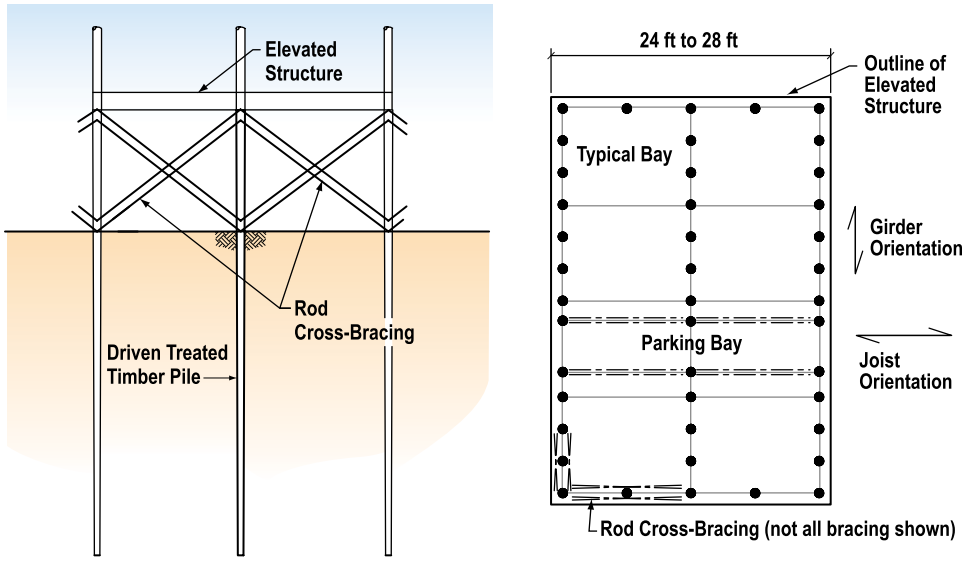
Input from Gulf Region builders helped improve the overall constructability of the FEMA 550 designs.

Open Foundations

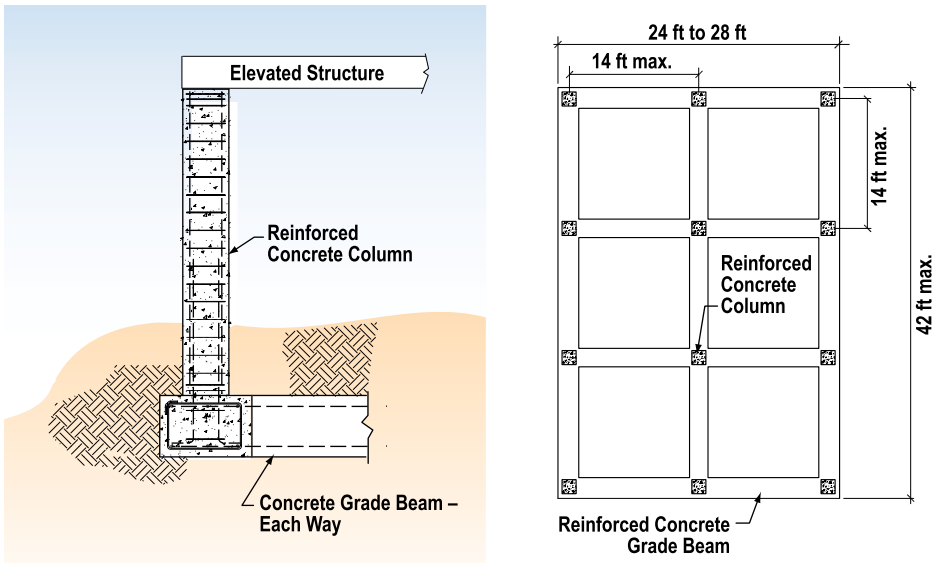
FEMA 550 engineers developed five designs for "open" foundations (open foundations are required by the NFIP in V-Zones and are recommended in Coastal A-Zones). They also developed two "closed" styles of foundations suitable for areas landward of Coastal A-Zones where wave heights are less than 1.5 feet.



Open/deep foundations using driven timber or steel pipe pilings - Section and plan view.



Braced timber pile foundation - Section and plan view.



Open/shallow foundations for section and plan view suitable for Coastal A Zones.

Of the five open foundation styles, three styles are open and deep (i.e. founded on pilings) and two are open and shallow (founded on reinforced concrete grade beams that function as footers). The open/deep foundations are suitable for V-Zones where breaking waves necessitate an open foundation style and where scour and erosion warrant founding homes on deeper soils. Of the three open and deep styles, two use driven timber or steel pipe piles with concrete grade beams and concrete columns and one uses braced timber piles. While designed for V-Zones, open/deep foundations are suitable for all flood zones.

The two open/shallow styles of foundation are similar to two of the V-Zone designs, but lack pilings. The designs are suitable for Coastal A Zones where breaking wave forces are less than V-Zones, and where scour and erosion is less problematic.

Closed Foundations

The two closed foundation styles consist of perimeter foundation walls. The closed styles are similar to construction commonly used outside of special flood hazard areas, but have the benefit of additional reinforcement required to resist breaking waves up to 1.5 feet high. They are suitable for areas landward of Coastal A Zones.

Table 1 (see page 26) summarizes the FEMA 550 foundation styles and their suggested use.

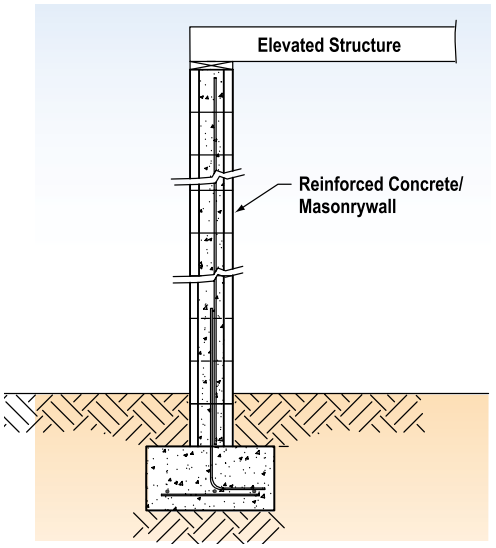
All designs were developed to resist flood and wind loads determined from ASCE 7. Designs for 3-second wind speeds from 120 mph to 150 mph are included. FEMA 550 includes designs for foundations heights (measured above site grade), up to 15 feet for open foundations and up to 8 feet for closed foundations. Preliminary estimates suggest that the designs will satisfy the needs of over 80% of the homes in the Gulf.

Using FEMA 550

The engineers who designed FEMA 550's seven foundation styles developed the designs to use a modular approach. This will allow users of the manual to assemble rectangular foundation "modules" to create non-rectangular homes. For example, two modules can be assembled to create "T" or "L" shaped homes; three can be assembled to create a "Z" shaped home. The developers of ICC-600 used a similar approach for wind design.

The base module was developed to support a range of dimensions and roof slopes. This also adds flexibility for the users of the manual. The foundations can be used to support homes from 24 to 42 feet deep, with roof pitches from 3:12 to 12:12.

Foundations were designed to resist the worst case loading for the range in building



Closed foundation suitable for areas landward of Coastal A- Zones where wave heights are 1.5 feet or less.

dimensions. For example, worst case uplift loads result from a 24-foot deep module with a low sloped roof; worst case lateral loads result from a 42-foot deep module with a steep roof.

This approach produces conservative designs. Throughout the manual, the authors remind readers that hiring an engineer to design a custom foundation for specific homes will produce more efficient and likely more cost effective designs.

FEMA 550 also contains guidance for design professionals. Calculations used to determine wind and flood loads are included, and guidance is provided on estimating wave heights, flood velocities, flood-borne debris impact loads and other criteria not readily available in consensus standards.▪

David Low, P.E., a professional engineer from Virginia, is one of the principal authors of FEMA 550. He has 25 years engineering experience, has been a contributing author of numerous FEMA publications and has been a member of several post-event assessment teams. David can be reached at ***dlow2003@verizon.net.***

Table 1: FEMA 550 Foundation Styles and Suggested Use.

Foundation		Case	V Zones	A Zones in Coastal Areas	
				Coastal A Zone	A Zone
Open Foundation (deep)	Timber pile	A	✓	✓	✓
	Steel pipe pile with concrete column and grade beam	B	✓	✓	✓
	Timber pile with concrete column and grade beam	C	✓	✓	✓
Open Foundation (shallow)	Concrete column and grade beam	D	NR	✓	✓
	Concrete column and grade beam with slab	G	NR	✓	✓
Closed Foundation (shallow)	Reinforced masonry – crawlspace	E	✘	NR	✓
	Reinforced masonry – stem wall	F	✘	NR	✓

✓ = Acceptable
NR = Not Recommended
✘ = Not Permitted

FEMA 550 is available for download at **www.fema.gov/library/**. A free copy can be ordered by calling the FEMA Publications warehouse at 1-800-480-2520.