

Building on Strong and Safe Foundations

Introduction

The purpose of this design manual is to provide recommended foundation designs and guidance for rebuilding homes destroyed by hurricanes in coastal areas. In addition, the manual is intended to provide guidance in designing and building safer and less vulnerable homes to reduce the risk to life and property.

Past storms such as Hurricanes Andrew, Hugo, Charley, Katrina, and Rita, and recent events such as Hurricane Ike continue to show the vulnerability of our “built environment” (Figure 1). While good design and construction cannot totally eliminate risk, every storm has shown that sound design and construction can significantly reduce the risk to life and damage to property. With that in mind, the Federal Emergency Management Agency (FEMA) has developed this manual to help the community of homebuilders, contractors, and local engineering professionals in rebuilding homes destroyed by hurricanes, and designing and building safer and less vulnerable new homes.

Figure 1.
Damage to residential
properties as a result
of Hurricane Katrina's
winds and storm surge.
Note the building that
was knocked off its
foundation (circled).

SOURCE: HURRICANE
 KATRINA MAT PHOTO



Intent of the Manual

The intent of the manual is to provide homebuilders, contractors, and engineering professionals with a series of recommended foundation designs that will help create safer and stronger buildings in coastal areas. The designs are intended to help support rebuilding efforts after coastal areas have been damaged by floods, high winds, or other natural hazards.

The foundations may differ somewhat from traditional construction techniques; however, they represent what are considered to be some of the better approaches to constructing strong and safe foundations in hazardous coastal areas. The objectives used to guide the development of this manual are:

- To provide residential foundation designs that will require minimal engineering oversight
- To provide foundation designs that are flexible enough to accommodate many of the homes identified in *A Pattern Book for Gulf Coast Neighborhoods* prepared for the Mississippi Governor’s Rebuilding Commission on Recovery, Rebuilding, and Renewal (see Appendix B)
- To utilize "model" layouts so that many homes can be constructed without significant additional engineering efforts

The focus of this document is on the foundations of residential buildings. The assumption is that those who are designing and building new homes will be responsible for ensuring that the building itself is designed according to the latest building code (International Building Code® [IBC®], International Residential Code® [IRC®], and FEMA guidance) and any local requirements. The user of this manual is directed to other publications that also address disaster-resistant construction (see Appendix G).

Although the foundation designs are geared to the coastal environment subject to storm surge, waves, floating debris, and high winds, several are suitable for supporting homes on sites protected by levees and floodwalls or in riverine areas subjected to high-velocity flows. Design professionals can be contacted to ensure the foundation designs provided in this manual are suitable for specific sites.

This manual contains closed foundation designs for elevating homes up to 8 feet above ground level and open foundation designs for elevating homes up to 15 feet above ground level. These upper limits are a function of constructability limitations and overturning and stability issues for more elevated foundations. Eight-foot tall foundations are a practical upper limit for 8-inch thick reinforced concrete masonry unit (CMU) walls exposed to flood forces anticipated in non-coastal A zones. The upper limit of 15 feet for open foundations was established by estimating the amount a home needs to be elevated to achieve the 2005 Advisory Base Flood Elevations (ABFEs) as determined in response to Hurricanes Katrina and Rita. The ABFEs published in the Hurricane Recovery Maps were compared to local topographic maps for the Gulf Coast. The comparison revealed that providing foundation designs up to 15 feet tall would allow over 80 percent of the homes damaged by Hurricane Katrina to be protected from flood events reflected in the ABFEs and in the Hurricane Recovery Maps. Many homes can be elevated to the BFE on foundations that are 4 feet tall or less.

This updated edition of FEMA 550 introduces the Case H foundation, which is an open/deep foundation developed for use in coastal high hazard areas (V zones). It is also appropriate to use the Case H foundation in Coastal A and non-coastal A zones. Case H foundations incorporate elevated reinforced concrete beams that provide three important benefits. One, the elevated beams work in conjunction with the reinforced concrete columns and grade beams to produce a structural frame that is more efficient at resisting lateral loads than the grade beams and cantilevered columns used in other FEMA 550 open foundations. The increased efficiency allows foundations to be constructed with smaller columns that are less exposed to flood forces.

The second benefit is that the elevated reinforced concrete beams provide a continuous foundation that can support many homes constructed to prescriptive designs from codes and standards such as the IRC, the American Forest and Paper Association's (AF&PA's) *Wood Frame Construction Manual for One- and Two-Family Dwellings (WFCM)*, and the International Code Council's (ICC's) *Standard for Residential Construction in High Wind Regions (ICC-600)*.

The third benefit that Case H foundations provide is the ability to support relatively narrow (14-foot wide) homes. It is anticipated that Case H foundations can be used for several styles of modular homes.



CAUTION: Although sites inside levees are not exposed to wave loads, sites immediately adjacent to floodwalls and levees can be exposed to extremely high flood velocities and scour if a breach occurs. Design professionals should be consulted before using these foundation designs on sites close to floodwalls or levees to determine if they are appropriate.

Using the Manual

The following information is needed to use this manual:

- Design wind speed and the Design Flood Elevation (DFE) at the site
- The flood zone(s) at the site
- Building layout
- Topographic elevation of existing building site
- Soil conditions for the site. Soil condition assumptions used in the load calculations are intentionally conservative. Users are encouraged to determine soil conditions at the site to potentially improve the cost-effectiveness of the design.

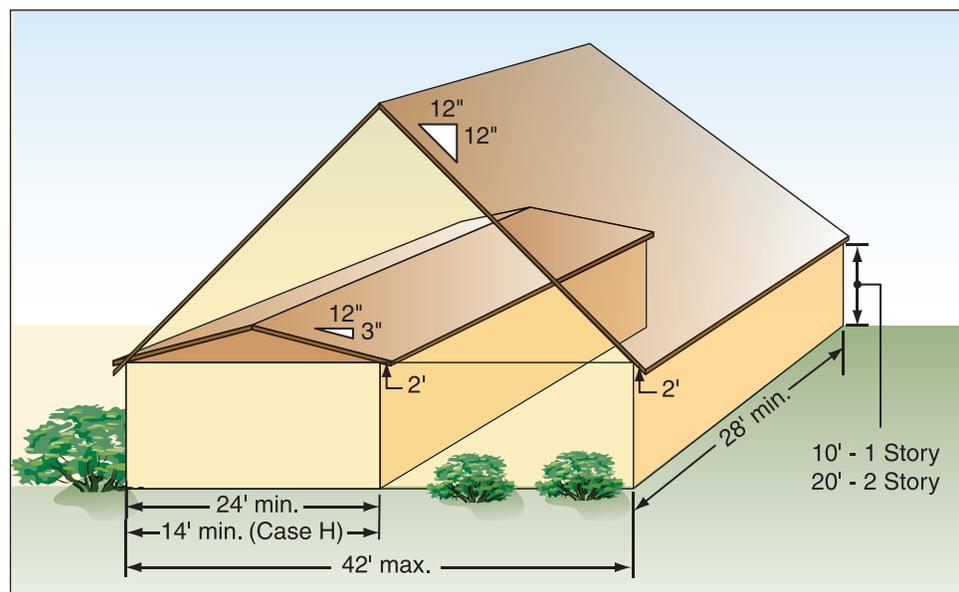
Most of the information can be obtained from the local building official or floodplain manager.

This document is not intended to supplant involvement from local design professionals. While the designs included can be used without modification (provided that the home to be elevated falls within the design criteria), consulting with local engineers should be considered. Local engineers may assist with the following:

- Incorporating local site conditions into the design
- Addressing and supporting unique features of the home
- Confirming the suitability of the designs for a specific home on a specific site
- Allowing use of value engineering to produce a more efficient design

These "prescriptive" designs have been developed to support homes with a range of dimensions, weights, and roof pitches. Figure 2 schematically shows the diverse range of dimensions

Figure 2.
Schematic range of home dimensions and roof pitches used as the basis for the foundation designs presented in this manual.



and roof pitches. Appendix C contains a complete list of criteria and assumptions used in these designs.

This manual concentrates on foundations that resist the extreme hurricane wind and flooding conditions found in many coastal areas. For successful, natural hazard-resistant installations, both the foundation and the home it supports must be properly designed and constructed to take all loads on the structure into the ground through the foundation. Designing and constructing the home to meet all the requirements of the IBC or the IRC is the minimum action necessary to producing hazard-resistant homes. However, any model code must contain minimum requirements. FEMA supports the use of best practice approaches for improved resistance to natural hazards.

The foundations presented in this manual have been designed to resist the flood, wind, and gravity loads specified in Appendix C and load combinations specified in the American Society of Civil Engineers' (ASCE's) *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-05). Although the designs provide significant resistance to gravity, lateral, and uplift loads, they have not been specifically designed for seismic events. In coastal areas where seismic risks exist, design professionals should confirm that the foundation designs presented herein are adequate to resist seismic loads on site.

To gain the benefits of a “best practices” approach, readers are directed to publications such as FEMA 499, *Home Builder's Guide to Coastal Construction Technical Fact Sheet Series*, and FEMA 55, *Coastal Construction Manual*. A more complete list of available publications is contained in Appendix G.

Organization of the Manual

There are five chapters and nine appendices in this manual. The intent is to cover the essential information in the chapters and provide all the details in the appendices. Chapter 1 provides a description of the different types of hazards that must be considered in the design of a residential building foundation in a coastal area. The primary issues related to designing foundations for residential buildings are described in Chapter 2. Chapter 3 provides guidance on how to determine the magnitude of the loads placed on a building by a particular natural hazard event or a combination of events. The different foundation types and methods of construction foundation for a residential building are discussed in Chapter 4. Chapter 5 and Appendix A present foundation designs to assist the homebuilders, contractors, and local engineering professionals in developing safe and strong foundations.

In addition to Chapters 1 through 5 and Appendix A, the following appendices are presented herein:

- Appendix B presents examples of how the foundation designs in this manual can be used with some of the homes in the publication *A Pattern Book for Gulf Coast Neighborhoods*.
- Appendix C provides a list of assumptions used in developing the foundation design presented in this manual.

- Appendix D presents detailed calculations on how to design the foundation of residential buildings. Two examples, one for open foundations and the other for closed foundations, are included.
- Appendix E provides cost information that the homebuilders can use to estimate the cost of installing the foundation systems proposed in this manual.
- Appendix F includes fact sheets contained in FEMA 499 (*Home Builder's Guide to Coastal Construction Technical Fact Sheet Series*) and a recovery advisory contained in FEMA P-757 (*Hurricane Ike in Texas and Louisiana: Mitigation Assessment Team Report, Building Performance Observations, Recommendations, and Technical Guidance*) that are pertinent to construction in coastal areas.
- Appendix G presents a list of references and other FEMA publications that can be of assistance to the users of this manual.
- Appendix H contains a glossary of terms used in this manual.
- Appendix I defines abbreviations and acronyms used in this manual.

Limitations of the Manual

This manual has been provided to assist in reconstruction efforts after coastal areas have been damaged by floods, high winds, or other natural hazards. Builders, architects, or engineers using this manual assume responsibility for the resulting designs and their performance during a natural hazard event.

The foundation designs and analyses presented in this manual were based on ASCE 7-02 and the 2003 version of the IRC. While FEMA 550 was being developed, ASCE released its 2005 edition of ASCE 7 (ASCE 7-05) and the ICC issued their 2006 editions of the IBC and IRC. The ASCE 7 revisions did not affect the load calculations controlling the designs and there were no substantive flood provision changes to the IRC that affect foundation designs in coastal areas.

This Second Edition of FEMA 550 is consistent with the 2009 editions of the IBC and IRC.