

Flood Resistant Design and Construction

This document uses both the
International System of Units (SI)
and customary units

American Society of Civil Engineers

**Flood Resistant Design
and Construction**

This document uses both the International System of Units (SI)
and customary units.



Published by the American Society of Civil Engineers

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191
www.pubs.asce.org

Cataloging-in-Publication Data on file with the Library of Congress

Any statements expressed in these materials are those of the individual authors and do not necessarily represent the views of ASCE, which takes no responsibility for any statement made herein. No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE.

ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefore. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing this information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

ASCE and American Society of Civil Engineers—
Registered in U.S. Patent and Trademark Office.

Photocopies: Authorization to photocopy material for internal or personal use under circumstances not falling within the fair use provisions of the Copyright Act is granted by ASCE to libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$25.00 per article is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923. The identification for this book is 0-7844-0818-1/06/\$25.00. Requests for special permission or bulk copying should be addressed to Permissions & Copyright Dept., ASCE.

Copyright © 2006 by the American Society of Civil Engineers.
All Rights Reserved.
ISBN 0-7844-0818-1
Manufactured in the United States of America.

STANDARDS

In April 1980, the Board of Direction approved ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Codes and Standards Activities Committee. The consensus process includes balloting by the Balanced Standards Committee, which is composed of Society members and nonmembers, balloting by the membership of ASCE as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding 5 years.

The following Standards have been issued:

- ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures
- ANSI/ASCE 2-91 Measurement of Oxygen Transfer in Clean Water
- ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs
- ASCE 4-98 Seismic Analysis of Safety-Related Nuclear Structures
- Building Code Requirements for Masonry Structures (ACI 530-02/ASCE 5-02/TMS 402-02) and Specifications for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02)
- ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures
- ANSI/ASCE 8-90 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members
- ANSI/ASCE 9-91 listed with ASCE 3-91
- ASCE 10-97 Design of Latticed Steel Transmission Structures
- SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings
- ASCE 12-05 Guideline for the Design of Urban Subsurface Drainage
- ASCE 13-05 Standard Guidelines for Installation of Urban Subsurface Drainage
- ASCE 14-05 Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage
- ASCE 15-98 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)
- ASCE 16-95 Standard for Load Resistance Factor Design (LRFD) of Engineered Wood Construction
- ASCE 17-96 Air-Supported Structures
- ASCE 18-96 Standard Guidelines for In-Process Oxygen Transfer Testing
- ASCE 19-96 Structural Applications of Steel Cables for Buildings
- ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations
- ASCE 21-96 Automated People Mover Standards—Part 1
- ASCE 21-98 Automated People Mover Standards—Part 2
- ASCE 21-00 Automated People Mover Standards—Part 3
- SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings
- ASCE/SEI 24-05 Flood Resistant Design and Construction
- ASCE 25-97 Earthquake-Actuated Automatic Gas Shut-Off Devices
- ASCE 26-97 Standard Practice for Design of Buried Precast Concrete Box Sections
- ASCE 27-00 Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction
- ASCE 28-00 Standard Practice for Direct Design of Precast Concrete Box Sections for Jacking in Trenchless Construction
- SEI/ASCE/SFPE 29-99 Standard Calculation Methods for Structural Fire Protection
- SEI/ASCE 30-00 Guideline for Condition Assessment of the Building Envelope
- SEI/ASCE 31-03 Seismic Evaluation of Existing Buildings
- SEI/ASCE 32-01 Design and Construction of Frost-Protected Shallow Foundations
- EWRI/ASCE 33-01 Comprehensive Transboundary International Water Quality Management Agreement
- EWRI/ASCE 34-01 Standard Guidelines for Artificial Recharge of Ground Water
- EWRI/ASCE 35-01 Guidelines for Quality Assurance of Installed Fine-Pore Aeration Equipment
- CI/ASCE 36-01 Standard Construction Guidelines for Microtunneling
- SEI/ASCE 37-02 Design Loads on Structures During Construction
- CI/ASCE 38-02 Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data
- EWRI/ASCE 39-03 Standard Practice for the Design and Operation of Hail Suppression Projects
- ASCE/EWRI 40-03 Regulated Riparian Model Water Code
- ASCE/EWRI 42-04 Standard Practice for the Design and Operation of Precipitation Enhancement Projects
- ASCE/SEI 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
- ASCE/EWRI 44-05 Standard Practice for the Design and Operation of Supercooled Fog Dispersal Projects
- ASCE/EWRI 45-05 Standard Guidelines for the Design of Urban Stormwater Systems
- ASCE/EWRI 46-05 Standard Guidelines for the Installation of Urban Stormwater Systems
- ASCE/EWRI 47-05 Standard Guidelines for the Operation and Maintenance of Urban Stormwater Systems

This page intentionally left blank

FOREWORD

The material presented in this standard has been prepared in accordance with recognized engineering principles. This standard should not be used without first securing competent advice with respect to its suitability for any given application. The publication of the material contained herein is not intended as a representation

or warranty on the part of the American Society of Civil Engineers, or of any other person named herein, that this information is suitable for any general or particular use or promises freedom from infringement of any patent or patents. Anyone making use of this information assumes all liability from such use.

ACKNOWLEDGEMENTS

The American Society of Civil Engineers (ASCE) acknowledges the work of the Flood Resistant Design and Construction Standards Committee of the Codes and Standards Activities Division of the Structural Engineering Institute. This group comprises individuals from many backgrounds including consulting engineering, research, construction industry, education, government, design, and private practice.

This revision of the standard began in 2001 and incorporates information as described in the commentary.

This standard was prepared through the consensus standards process by balloting in compliance with procedures of ASCE's Codes and Standards Activities Committee. Those individuals who serve on the Standards Committee are

Conrad Battreal
William L. Coulbourne, P.E.
Shou Shan Fan, Ph.D.
Daryle L. Fontenot
Kenneth A. Ford
James S. Graham, Jr., P.E.
Michael Graham
Barbara D. Hayes
John L. Ingargiola
Christopher P. Jones, P.E., Vice Chair
Thomas MacAllen
Joseph J. Messersmith, Jr., P.E.
Kim Paarlberg
Spencer M. Rogers, Jr.
Herbert S. Saffir, P.E., L.S.
Edward M. Salisbury, P.E.
Erez Sela, P.E.
Paul R. Tertell
Harry B. Thomas, P.E., Chair
Theodore C. Van Kirk
Robert A. Wessel
Thomas G. Williamson, P.E.

CONTENTS

Standards	iii
Foreword	v
Acknowledgements	vi
1.0 GENERAL	1
1.1 Scope	1
1.2 Definitions	2
1.3 Identification of Flood Hazard Areas	6
1.4 Identification of Floodprone Structures	6
1.4.1 General	6
1.4.2 Consideration for Flood Protective Works	6
1.4.3 Classification of Structures	6
1.5 Basic Design and Construction Requirements	8
1.5.1 General	8
1.5.2 Elevation Requirements	8
1.5.3 Foundation Requirements	8
1.5.3.1 Geotechnical Considerations	8
1.5.3.2 Foundation Depth	8
1.5.3.3 Foundation Walls	8
1.5.3.4 Piers, Posts, Columns, or Piles	9
1.5.4 Use of Fill	9
1.5.5 Anchorage and Connections	9
1.6 Loads in Flood Hazard Areas	9
1.6.1 General	9
1.6.2 Combination of Loads	9
2.0 BASIC REQUIREMENTS FOR FLOOD HAZARD AREAS THAT ARE NOT IDENTIFIED AS COASTAL HIGH HAZARD AREAS AND COASTAL A ZONES	9
2.1 Scope	9
2.2 Development in Floodways	9
2.3 Elevation Requirements	10
2.4 Use of Fill	10
2.4.1 Structural Fill	10
2.5 Slabs-on-Grade and Footings	10
2.5.1 Use of Slabs-on-Grade	10
2.5.2 Footing Design	11
2.6 Enclosures Below the Design Flood Elevation	11
2.6.1 Required Openings in Foundation Walls	11
2.6.1.1 Openings in Breakaway Walls	11
2.6.2 Design of Openings	11
2.6.2.1 Nonengineered Openings	11
2.6.2.2 Engineered Openings	11
3.0 HIGH RISK FLOOD HAZARD AREAS	12
3.1 Scope	12
3.2 Alluvial Fan Areas	12
3.2.1 Protective Works in Alluvial Fan Areas	12
3.3 Flash Flood Areas	12
3.3.1 Protective Works in Flash Flood Areas	13
3.4 Mudslide Areas	13
3.4.1 Protective Works in Mudslide Areas	13
3.5 Erosion-Prone Areas	13
3.5.1 Protective Works in Erosion-Prone Areas	13

3.6	High Velocity Flow Areas	13
3.6.1	Protective Works in High Velocity Flow Areas	13
3.7	Areas Subject to Wave Action	13
3.7.1	Coastal High Hazard Areas and Coastal A Zones	13
3.7.2	Other High Velocity Wave Action Areas	13
3.8	Ice Jam and Debris Areas	13
3.8.1	Protective Works in Ice Jam and Debris Areas	14
4.0	COASTAL HIGH HAZARD AREAS AND COASTAL A ZONES	14
4.1	Scope	14
4.1.1	Identification of Coastal High Hazard Areas and Coastal A Zones	14
4.2	General	14
4.3	Siting	14
4.4	Elevation Requirements	14
4.5	Foundation Requirements	14
4.5.1	General	14
4.5.2	Special Geotechnical Considerations	15
4.5.3	Foundation Depth	15
4.5.4	Use of Fill	15
4.5.5	Pile Foundations	15
4.5.5.1	Attachments to Piles	16
4.5.5.2	Piles Terminating in Caps at or Below Grade	16
4.5.5.3	Piles Extending to Superstructure (Structure Framing)	16
4.5.5.4	Wood Piles	16
4.5.5.5	Steel H Piles	16
4.5.5.6	Concrete-Filled Steel Pipe Piles and Shells	16
4.5.5.7	Prestressed Concrete Piles and Precast Concrete Piles	17
4.5.5.8	Cast-in-Place Concrete Piles	17
4.5.6	Pile Design	17
4.5.6.1	Pile Capacity	17
4.5.6.2	Capacity of the Supporting Soils	17
4.5.6.3	Minimum Penetration	17
4.5.6.4	Foundation Pile Spacing	17
4.5.6.5	Pile Caps	17
4.5.6.6	Timber Pile Connections	17
4.5.6.7	Steel Pile Connections	18
4.5.6.8	Concrete Pile Connections	18
4.5.6.9	Pile Splicing	18
4.5.6.10	Mixed Types of Piling and Multiple Types of Installation Methodology	18
4.5.7	Posts, Piers, and Columns	18
4.5.7.1	Wood Posts	18
4.5.7.2	Reinforced Masonry Columns	18
4.5.7.3	Reinforced Concrete Columns	18
4.5.8	Footings, Mats, Rafts, and Slabs-on-Grade	18
4.5.9	Grade Beams	19
4.5.10	Bracing	19
4.5.11	Shear Walls	19
4.6	Enclosed Areas Below Design Flood Elevation	19
4.6.1	Breakaway Walls	19
4.6.2	Openings in Breakaway Walls in Coastal A Zones	19
4.7	Erosion Control Structures	20
4.8	Decks, Concrete Pads, and Patios	20

5.0	MATERIALS	20
5.1	General	20
5.2	Specific Materials Requirements for Flood Hazard Areas	21
5.2.1	Metal Connectors and Fasteners	21
5.2.2	Structural Steel	21
5.2.2.1	Corrosive Environments	21
5.2.2.2	Noncorrosive Environments	21
5.2.3	Concrete	21
5.2.4	Masonry	21
5.2.5	Wood and Timber	21
5.2.6	Finishes	21
6.0	DRY AND WET FLOODPROOFING	22
6.1	Scope	22
6.2	Dry Floodproofing	22
6.2.1	Dry Floodproofing Limitations	22
6.2.2	Dry Floodproofing Requirements	22
6.2.3	Limits on Human Intervention	22
6.3	Wet Floodproofing	23
6.3.1	Wet Floodproofing Limitations on Use	23
6.3.2	Wet Floodproofing Requirements	23
7.0	UTILITIES	23
7.1	General	23
7.2	Electrical Service	23
7.2.1	Service Conduits and Cables	23
7.2.2	Exposed Conduits and Cables	24
7.2.3	Electric Meters	24
7.2.4	Disconnect Switches and Circuit Breakers	24
7.2.5	Electric Elements Installed Below Minimum Elevations	24
7.3	Plumbing Systems	25
7.3.1	Buried Plumbing Systems	25
7.3.2	Exposed Plumbing Systems	25
7.3.3	Plumbing Systems Installed Below Minimum Elevations	25
7.3.4	Sanitary Systems	25
7.4	Mechanical, Heating, Ventilation, and Air Conditioning Systems	25
7.4.1	Tanks	25
7.5	Elevators	25
8.0	BUILDING ACCESS	26
8.1	General	26
9.0	MISCELLANEOUS CONSTRUCTION	26
9.1	General	26
9.2	Decks, Porches, and Patios	26
9.2.1	Attached Decks, Porches, and Patios	26
9.2.2	Detached Decks, Porches, and Patios	26
9.3	Garages	27
9.3.1	Attached Garages and Carports	27
9.3.2	Detached Garages and Carports	27
9.4	Chimneys and Fireplaces	27
9.5	Pools	27
9.6	Storage Tanks	27
10.0	REFERENCES	28

Commentary

C1.0	GENERAL	29
C1.1	Scope	29
C1.2	Definitions	29
C1.3	Identification of Flood Hazard Areas	31
C1.4	Identification of Floodprone Structures	33
C1.4.1	General	33
C1.4.2	Consideration for Flood Protective Works	33
C1.4.3	Classification of Structures	34
C1.5	Basic Design and Construction Requirements	34
C1.5.1	General	34
C1.5.2	Elevation Requirements	34
C1.5.3	Foundation Requirements	35
C1.5.3.1	Geotechnical Considerations	35
C1.5.3.2	Foundation Depth	35
C1.5.3.3	Foundation Walls	35
C1.5.3.4	Piers, Posts, Columns, or Piles	35
C1.5.4	Use of Fill	35
C1.5.5	Anchorage and Connections	36
C1.6	Loads in Flood Hazard Areas	36
C1.6.1	General	36
C2.0	BASIC REQUIREMENTS FOR FLOOD HAZARD AREAS THAT ARE NOT IDENTIFIED AS COASTAL HIGH HAZARD AREAS AND COASTAL A ZONES	36
C2.1	Scope	36
C2.2	Development in Floodways	36
C2.3	Elevation Requirements	37
C2.4	Use of Fill	38
C2.4.1	Structural Fill	38
C2.5	Slabs-on-Grade and Footings	38
C2.5.1	Use of Slabs-on-Grade	38
C2.6	Enclosures Below the Design Flood Elevation	39
C2.6.1	Required Openings in Foundation Walls	39
C2.6.1.1	Openings in Breakaway Walls	39
C2.6.2	Design of Openings	39
C2.6.2.1	Nonengineered Openings	39
C2.6.2.2	Engineered Openings	39
C3.0	HIGH RISK FLOOD HAZARD AREAS	40
C3.1	Scope	40
C3.2	Alluvial Fan Areas	40
C3.3	Flash Flood Areas	41
C3.3.1	Protective Works in Flash Flood Areas	41
C3.4	Mudslide Areas	42
C3.5	Erosion-Prone Areas	42
C3.6	High Velocity Flow Areas	42
C3.8	Ice Jam and Debris Areas	43
C4.0	COASTAL HIGH HAZARD AREAS AND COASTAL A ZONES	43
C4.1	Scope	43
C4.1.1	Identification of Coastal High Hazard Areas and Coastal A Zones	43
C4.2	General	45
C4.3	Siting	46
C4.4	Elevation Requirements	47
C4.5.1	General	47
C4.5.3	Foundation Depth	47

C4.5.4	Use of Fill	48
C4.5.5	Pile Foundations	48
C4.5.5.4	Wood Piles	48
C4.5.5.6	Concrete-Filled Steel Pipe Piles and Shells	48
C4.5.5.8	Cast-in-Place Concrete Piles	48
C4.5.6.1	Pile Capacity	48
C4.5.6.2	Capacity of the Supporting Soils	49
C4.5.6.3	Minimum Penetration	49
C4.5.6.9	Pile Splicing	49
C4.5.7	Posts, Piers, and Columns	49
C4.5.7.3	Reinforced Concrete Columns	49
C4.5.8	Footings, Mats, Rafts, and Slabs-on-Grade	49
C4.5.9	Grade Beams	49
C4.5.10	Bracing	49
C4.5.11	Shear Walls	50
C4.6	Enclosed Areas Below Design Flood Elevation	50
C4.6.1	Breakaway Walls	50
C4.6.2	Openings in Breakaway Walls in Coastal A Zones	50
C5.0	MATERIALS	50
C5.1	General	50
C5.2.1	Metal Connectors and Fasteners	50
C5.2.2	Structural Steel	51
C5.2.3	Concrete	51
C5.2.5	Wood and Timber	51
C6.0	DRY AND WET FLOODPROOFING	51
C6.1	Scope	51
C6.2	Dry Floodproofing	52
C6.2.1	Dry Floodproofing Limitations	52
C6.2.2	Dry Floodproofing Requirements	52
C6.2.3	Limits on Human Intervention	52
C6.3	Wet Floodproofing Limitations	53
C7.0	UTILITIES	53
C7.1	General	53
C7.2	Electrical Service	54
C7.2.5	Electric Elements Installed Below Minimum Elevations	54
C7.3.3	Plumbing Systems Installed Below Minimum Elevations	54
C7.3.4	Sanitary Systems	54
C7.4	Mechanical, Heating, Ventilation, and Air Conditioning Systems	54
C7.4.1	Tanks	54
C7.5	Elevators	55
C8.0	BUILDING ACCESS	55
C8.1	General	55
C9.0	MISCELLANEOUS CONSTRUCTION	56
C9.2	Decks, Porches, and Patios	56
C9.2.1	Attached Decks, Porches, and Patios	56
C9.2.2	Detached Decks, Porches, and Patios	56
C9.3	Garages	56
C9.3.1	Attached Garages and Carports	56
C9.4	Chimneys and Fireplaces	56
C9.6	Storage Tanks	57
C10.0	REFERENCES	57
INDEX	59

This page intentionally left blank

Flood Resistant Design and Construction

1.0 GENERAL

1.1 SCOPE

This standard provides minimum requirements for flood-resistant design and construction of structures that are subject to building code requirements and that are located, in whole or in part, in flood hazard areas. This standard applies to new construction that includes: (a) new structures, including subsequent work to such structures, and (b) work classified as substantial repair or substantial improvement of an existing structure that is not an historic structure (see Fig. 1-1).

The general provisions of this section shall apply to all new construction and substantial improvements

in flood hazard areas. In addition to the requirements of this section (see Fig. 1-2):

1. Section 2 shall apply to all new construction and substantial improvements in Flood Hazard Areas and High Risk Flood Hazard Areas except those that are identified as Coastal High Hazard Areas and Coastal A Zones;
2. Section 3 shall apply to all new construction and substantial improvements in High Risk Flood Hazard Areas;
3. Section 4 shall apply to all new construction and substantial improvements in Coastal High Hazard Areas and Coastal A Zones; and
4. Sections 5, 6, 7, 8, and 9 shall apply to all new construction and substantial improvements.

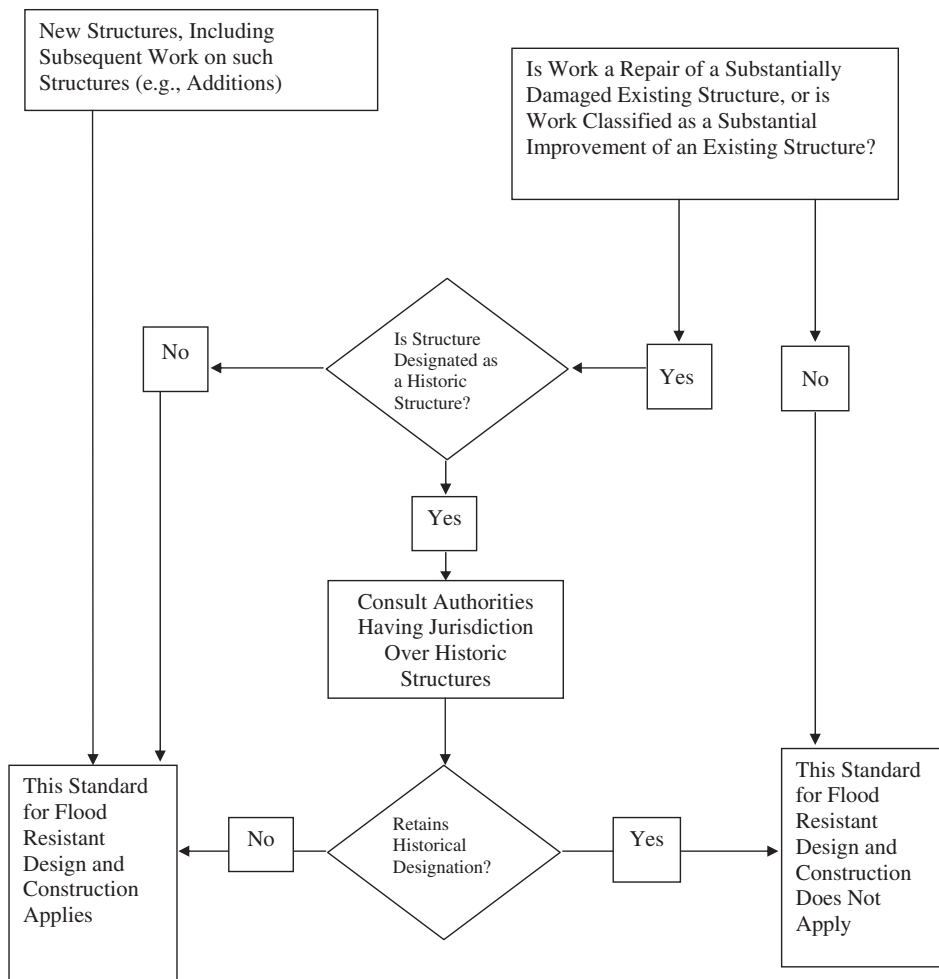


FIGURE 1-1. Illustration of Application of this Standard.