

Blast Protection of Buildings

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

American Society of Civil Engineers

Blast Protection of Buildings

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



**STRUCTURAL
ENGINEERING
INSTITUTE**

Published by the American Society of Civil Engineers

Cataloging-in-Publication data on file with Library of Congress

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

This standard was developed by a consensus standards development process which has been accredited by the American National Standards Institute (ANSI). Accreditation by ANSI, a voluntary accreditation body representing public and private sector standards development organizations in the U.S. and abroad, signifies that the standards development process used by ASCE has met the ANSI requirements for openness, balance, consensus, and due process.

While ASCE's process is designed to promote standards that reflect a fair and reasoned consensus among all interested participants, while preserving the public health, safety, and welfare that is paramount to its mission, it has not made an independent assessment of and does not warrant the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed herein. ASCE does not intend, nor should anyone interpret, ASCE's standards to replace the sound judgment of a competent professional, having knowledge and experience in the appropriate field(s) of practice, nor to substitute for the standard of care required of such professionals in interpreting and applying the contents of this standard.

ASCE has no authority to enforce compliance with its standards and does not undertake to certify products for compliance or to render any professional services to any person or entity.

ASCE disclaims any and all liability for any personal injury, property damage, financial loss or other damages of any nature whatsoever, including without limitation any direct, indirect, special, exemplary, or consequential damages, resulting from any person's use of, or reliance on, this standard. Any individual who relies on this standard assumes full responsibility for such use.

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

Photocopies and reprints. You can obtain instant permission to photocopy ASCE publications by using ASCE's online permission service (<http://pubs.asce.org/permissions/requests/>). Requests for 100 copies or more should be submitted to the Reprints Department, Publications Division, ASCE (address above); e-mail: permissions@asce.org. A reprint order form can be found at <http://pubs.asce.org/support/reprints/>.

Copyright © 2011 by the American Society of Civil Engineers.
All Rights Reserved.
ISBN 978-0-7844-1188-9
Manufactured in the United States of America.

18 17 16 15 14 13 12 11 1 2 3 4 5

STANDARDS

In 2006, the Board of Direction approved the revision to the 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 Society's Codes and Standards Committee (CSC). The consensus process includes balloting by a balanced standards committee made up of Society members and nonmembers, balloting by the membership of the Society as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding five years.

The following standards have been issued:

- ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures
- ASCE/EWRI 2-06 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 7-10 Minimum Design Loads for Buildings and Other Structures
- SEI/ASCE 8-02 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/EWRI 12-05 Guideline for the Design of Urban Subsurface Drainage
- ASCE/EWRI 13-05 Standard Guidelines for Installation of Urban Subsurface Drainage
- ASCE/EWRI 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/SEI 19-10 Structural Applications of Steel Cables for Buildings
- ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations
- ANSI/ASCE/T&DI 21-05 Automated People Mover Standards—Part 1
- ANSI/ASCE/T&DI 21.2-08 Automated People Mover Standards—Part 2
- ANSI/ASCE/T&DI 21.3-08 Automated People Mover Standards—Part 3
- ANSI/ASCE/T&DI 21.4-08 Automated People Mover Standards—Part 4
- SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings
- ASCE/SEI 24-05 Flood Resistant Design and Construction
- ASCE/SEI 25-06 Earthquake-Actuated Automatic Gas Shutoff 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
- ASCE/SEI/SFPE 29-05 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 33-09 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/SEI 41-06 Seismic Rehabilitation of Existing Buildings
- 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
- ASCE/SEI 48-11 Design of Steel Transmission Pole Structures
- ASCE/EWRI 50-08 Standard Guideline for Fitting Saturated Hydraulic Conductivity Using Probability Density Functions
- ASCE/EWRI 51-08 Standard Guideline for Calculating the Effective Saturated Hydraulic Conductivity
- ASCE/SEI 52-10 Design of Fiberglass-Reinforced Plastic (FRP) Stacks

ASCE/G-I 53-10 Compaction Grouting Consensus Guide
ASCE/EWRI 54-10 Standard Guideline for the Geostatistical
Estimation and Block-Averaging of Homogeneous and Isotropic
Saturated Hydraulic Conductivity
ASCE/SEI 55-10 Tensile Membrane Structures
ANSI/ASCE/EWRI 56-10 Guidelines for the Physical Security
of Water Utilities

ANSI/ASCE/EWRI 57-10 Guidelines for the Physical Security
of Wastewater/Stormwater Utilities
ASCE/T&DI/ICPI 58-10 Structural Design of Interlocking Concrete
Pavement for Municipal Streets and Roadways
ASCE/SEI 59-11 Blast Protection of Buildings

CONTENTS

		Page
	FOREWORD	xiii
	ACKNOWLEDGMENTS	xv
1	General	1
1.1	Scope	1
1.2	Definitions	1
1.3	Symbols and Notation	3
1.4	Qualifications	4
1.5	Information Sensitivity	4
1.6	Consensus Standards and Other Referenced Documents	4
2	Design Considerations	5
2.1	Scope	5
2.2	Risk Assessment	5
2.2.1	Consequence Analysis	5
2.2.2	Threat Analysis	5
2.2.3	Vulnerability Analysis	5
2.2.4	Risk Analysis	5
2.3	Risk Reduction	5
2.3.1	Consequence Reduction	5
2.3.2	Threat Reduction	5
2.4	Risk Acceptance	6
3	Performance Criteria	7
3.1	Scope	7
3.2	Design Objectives	7
3.2.1	Limit Structural Collapse	7
3.2.2	Maintain Building Envelope	7
3.2.3	Minimize Flying Debris	7
3.3	Levels of Protection	7
3.3.1	Structural Damage	7
3.3.2	Element Damage	7
3.3.3	Glazing Behavior	7
3.3.4	Door Behavior	7
3.4	Response Limits	8
3.4.1	Flexural Elements	8
3.4.2	Compression Elements	8
3.5	Element Strength	8
3.5.1	Strength Increase Factors	8
3.5.2	Strength Reduction Factors	8
3.5.3	Remaining Strength	8
3.6	Consensus Standards and Other Referenced Documents	8
4	Blast Loads	13
4.1	General	13
4.1.1	Scope	13
4.1.2	Permitted Procedures	13
4.2	Basic Procedure for External Blast	13
4.2.1	Scope	13
4.2.2	Directly Loaded Surfaces	13
4.2.3	Indirectly Loaded Surfaces	13
4.3	Basic Procedure for Internal Blast	19
4.3.1	Scope	19

4.4	4.3.2	Procedure	19
		Other Procedures	19
5		Fragmentation	21
	5.1	General	21
		5.1.1 Scope	21
	5.2	Design Requirements	21
	5.3	Analytical Procedures	21
		5.3.1 Acceptable Analytical Methods	21
		5.3.2 Limits on Analytical Procedures	21
		5.3.3 Complex Modeling Methods	21
6		Structural Systems	23
	6.1	General Provisions.	23
		6.1.1 Purpose	23
		6.1.2 Scope and Application	23
	6.2	Structural Modeling and Analysis.	23
		6.2.1 Analytical Methods	23
		6.2.2 Materials.	23
		6.2.3 Modeling of Elements.	24
		6.2.4 Connections and Joints	25
		6.2.5 Application of Loads	25
		6.2.6 Mass	26
	6.3	Structural Design	26
		6.3.1 Structural Systems.	26
	6.4	Response Characteristics	26
		6.4.1 Close-In Effects	26
		6.4.2 Far-Range Effects	27
	6.5	Consensus Standards and Other Referenced Documents	27
7		Protection of Spaces	29
	7.1	General Provisions.	29
	7.2	Walls and Slabs Isolating Internal Threats	29
		7.2.1 Scope	29
		7.2.2 Threat Locations for Buildings with Controlled Access	29
		7.2.3 Design Provisions for Walls and Slabs Isolating Internal Threats	29
		7.2.4 Stairwell Enclosures.	29
		7.2.5 Hardened Plenums.	29
	7.3	Safe Havens	29
		7.3.1 Design Considerations	29
		7.3.2 Applicable Loads and Performance.	29
		7.3.3 Resistance to Progressive Collapse	30
		7.3.4 Location within Building	30
		7.3.5 Accessibility to Egress	30
		7.3.6 Fire Rating.	30
	7.4	Consensus Standards and Other Referenced Documents	30
8		Exterior Envelope	31
	8.1	Design Intent.	31
		8.1.1 General	31
		8.1.2	31
	8.2	Design Procedures	31
		8.2.1 General	31
		8.2.2 Response Criteria	31
		8.2.3 Analytical Methods	31
		8.2.4 Balanced Design.	31
		8.2.5 Flying Fragments	31
	8.3	Fenestration	31
		8.3.1 General	31

8.3.2	Blast-Mitigating Window Systems	31
8.3.3	Curtain Wall Systems	32
8.3.4	Skylights	32
8.3.5	Operable Windows	32
8.3.6	Doors	32
8.4	Non-Load-Bearing Exterior Walls	32
8.4.1	General	32
8.4.2	Cast-in-Place, Precast, and Tilt-Up Concrete Walls	33
8.4.3	Pretensioned and Posttensioned Concrete Wall Panels	33
8.4.4	Masonry Walls	33
8.4.5	Steel Wall Systems	33
8.4.6	Other Wall Systems	33
8.5	Roof Systems	33
8.5.1	General	33
8.5.2	Flat Slabs	33
8.5.3	Metal Deck	33
8.5.4	Composite Construction	33
8.5.5	Steel Joists and Joist Girders	33
8.5.6	Other Roof Systems	33
8.6	Other Exterior Envelope Elements	33
8.7	Hazard-Mitigating Retrofits	33
8.7.1	General	33
8.7.2	Security Window Films	34
8.7.3	Blast Curtains	34
8.7.4	Catch Bar Systems	34
8.7.5	Secondary Window System	34
8.7.6	Window Replacement	34
8.7.7	Geotextile Fabrics	34
8.7.8	Fiber-Reinforced Polymers	34
8.7.9	Secondary Wall System	34
8.7.10	Other Retrofits	34
8.8	Amplification and Reduction of Blast Loads	34
8.8.1	Building Shape and Site	34
8.8.2	Venting	34
8.9	Consensus Standards and Other Referenced Documents	34
9	Materials Detailing	35
9.1	General	35
9.1.1	Scope	35
9.1.2	Structural Interaction	35
9.1.3	Materials	35
9.1.4	Detailing	35
9.1.5	Controlling Loads	35
9.1.6	Achieving Design Intent	35
9.1.7	Use of Reference Documents	35
9.1.8	Special Inspection	35
9.2	Concrete	35
9.2.1	Scope	35
9.2.2	General Reinforced Concrete Detailing Requirements	35
9.2.3	Columns	35
9.2.4	Beams	36
9.2.5	Beam-Column Joints	36
9.2.6	Slabs	36
9.2.7	Walls	37
9.2.8	Tension Ties	37
9.3	Structural Steel	37
9.3.1	Scope	37
9.3.2	General Structural Steel Requirements	37
9.4	Steel/Concrete Composite	37
9.4.1	Scope	37
9.4.2	Concrete Slab on Metal Deck	37
9.5	Masonry	37
9.5.1	Scope	37
9.5.2	General Design Requirements	38

9.5.3	General Material Requirements	38
9.5.4	General Detailing Requirements	38
9.5.5	Walls	38
9.6	Fiber Reinforced Polymer (FRP) Composite Materials.	38
9.6.1	Scope	38
9.6.2	Strength Increase Factors	38
9.6.3	General	39
9.6.4	FRP Strengthened Reinforced Concrete Beams and Slabs	39
9.6.5	FRP Strengthened Masonry Walls	39
9.6.6	FRP Concrete Column Confinement Requirements and Limitations	39
9.6.7	FRP Solid Sections	39
9.7	Other Materials	39
9.7.1	Aluminum	39
9.7.2	Wood.	39
9.7.3	Cold-Formed Steel Framing.	39
9.8	Consensus Standards and Other Referenced Documents	39
10	Performance Qualification	41
10.1	Scope.	41
10.2	Peer Review	41
10.3	Site Perimeter Components	41
10.3.1	Performance Qualification by Full-Scale Testing.	41
10.3.2	Performance Qualification by Analysis and Design	41
10.4	Building Structural Components	41
10.4.1	Performance Qualification by Full-Scale Testing.	41
10.4.2	Performance Qualification by Analysis and Design	42
10.5	Shielding Structures	42
10.5.1	Performance Qualification by Full-Scale Testing.	42
10.5.2	Performance Qualification by Analysis and Design	42
10.6	Building Façade Components	42
10.6.1	Glazing and Glazing Systems.	42
10.6.2	Doors	43
10.7	Building Nonstructural Components	44
10.7.1	Performance Qualification by Full-Scale Testing.	44
10.7.2	Performance Qualification by Analysis and Design	44
10.8	Consensus Standards and Other Referenced Documents	44
	COMMENTARY	45
C1	General	47
C1.1	Scope.	47
C1.4	Qualifications	47
C2	Design Considerations	49
C2.1	Scope.	49
C2.2	Risk Assessment	49
C2.2.1	Consequence Analysis.	49
C2.2.2	Threat Analysis	49
C2.2.3	Vulnerability Analysis.	50
C2.2.4	Risk Analysis	50
C2.3	Risk Reduction.	50
C2.3.1	Consequence Reduction.	50
C2.3.2	Threat Reduction	50
C2.4	Risk Acceptance	53
C3	Performance Criteria.	55
C3.2	Design Objectives	55
C3.2.1	Limit Structural Collapse	55
C3.2.2	Maintain Building Envelope	55
C3.2.3	Minimize Flying Debris.	55

C3.3	Levels of Protection	56
	C3.3.1 Structural Damage.	56
	C3.3.2 Element Damage	56
C3.4	Response Limits	56
	C3.4.1 Flexural Elements	56
	C3.4.2 Compression Elements	59
C3.5	Element Strength	60
	C3.5.1 Strength Increase Factors	60
	C3.5.2 Strength Reduction Factors	60
	C3.5.3 Remaining Strength	61
C4	Blast Loads.	63
	C4.1 General.	63
	C4.2 Basic Procedure for External Blast	63
	C4.2.1 Scope	63
	C4.2.2 Directly Loaded Surfaces	63
	C4.2.3 Indirectly Loaded Surfaces	63
	C4.3 Basic Procedure for Internal Blast	63
	C4.4 Other Procedures	63
C5	Fragmentation	65
	C5.1 General.	65
	C5.1.1 Scope	65
	C5.2 Design Requirements	65
	C5.2.1 Design Requirements	65
	C5.3 Analytical Procedures	65
	C5.3.1 Acceptable Analytical Methods.	65
	C5.3.2 Limits on Analytical Procedures	69
	C5.3.3 Complex Modeling Methods	70
C6	Structural Systems	71
	C6.1 General Provisions.	71
	C6.1.1 Purpose	71
	C6.1.2 Scope and Application	71
	C6.2 Structural Modeling and Analysis.	72
	C6.2.1 Analytical Methods	72
	C6.2.2 Materials.	74
	C6.2.3 Modeling of Elements.	74
	C6.2.4 Connections and Joints	77
	C6.2.6 Mass	78
	C6.3 Structural Design	78
	C6.3.1 Structural Systems.	78
	C6.4 Response Characteristics	79
	C6.4.1 Close-In Effects	79
	C6.4.2 Far-Range Effects	80
C7	Protection of Spaces	81
	C7.2 Walls and Slabs Isolating Internal Threats	81
	C7.2.3 Design Provisions for Walls and Slabs Isolating Internal Threats	81
	C7.2.4 Stairwell Enclosures.	81
	C7.3 Safe Havens	81
	C7.3.1 Design Considerations	81
	C7.3.2 Applicable Loads and Performance.	81
	C7.3.4 Location within Building	82
C8	Exterior Envelope	83
	C8.1 Design Intent.	83
	C8.2 Design Procedures	83

	C8.2.1	General	83
	C8.2.2	Response Criteria	83
	C8.2.3	Analytical Methods	83
	C8.2.4	Balanced Design.	84
	C8.2.5	Flying Fragments	85
C8.3		Fenestration	85
	C8.3.1	General	85
	C8.3.2	Blast-Mitigating Window Systems	85
	C8.3.3	Curtain Wall Systems	89
	C8.3.4	Skylights.	89
	C8.3.5	Operable Windows	89
	C8.3.6	Doors	89
C8.4		Non-Load-Bearing Exterior Walls.	91
	C8.4.1	General	91
	C8.4.2	Cast-in Place, Precast, and Tilt-Up Concrete Walls	91
	C8.4.3	Pretensioned and Posttensioned Concrete Wall Panels.	91
	C8.4.4	Masonry Walls.	91
	C8.4.5	Steel Wall Systems	91
C8.5		Roof Systems	91
C8.7		Hazard-Mitigating Retrofits	91
	C8.7.2	Security Window Films	91
	C8.7.5	Secondary Window Systems	92
	C8.7.8	Fiber-Reinforced Polymers	92
C8.8		Amplification and Reduction of Blast Loads	92
	C8.8.1	Building Shape and Site.	92
	C8.8.2	Venting.	92
C9		Materials Detailing.	95
	C9.1.1	Scope	95
	C9.1.2	Structural Interaction	95
	C9.1.3	Materials.	95
	C9.1.7	Use of Reference Documents	95
	C9.1.8	Special Inspection	95
C9.2		Concrete	95
	C9.2.1	Scope	95
	C9.2.2	General Reinforced Concrete Detailing Requirements.	95
	C9.2.3	Columns	96
	C9.2.4	Beams	96
	C9.2.5	Beam-Column Joints	97
	C9.2.6	Slabs	97
	C9.2.7	Walls.	97
	C9.2.8	Tension Ties.	97
C9.3		Structural Steel.	97
	C9.3.1	Scope	97
	C9.3.2	General Structural Steel Requirements	97
C9.4		Steel/Concrete Composite	98
	C9.4.1	Scope	98
	C9.4.2	Concrete Slab on Metal Deck.	98
C9.5		Masonry	98
	C9.5.1	Scope	98
	C9.5.2	General Design Requirements	99
	C9.5.5	99
C9.6		Fiber Reinforced Polymer (FRP) Composite Materials.	99
	C9.6.1	Scope	99
	C9.6.3	General	100
	C9.6.4	FRP-Strengthened, Reinforced Concrete Beams and Slabs	100
	C9.6.5	FRP Strengthened Masonry Walls.	101
	C9.6.6	FRP Concrete Column Confinement Requirements and Limitations	101
	C9.6.7	FRP Solid Sections	101
C9.7		Other Materials	101
	C9.7.1	Aluminum	102
	C9.7.3	Cold-Formed Steel Framing.	102

C10	Performance Qualification	103
C10.1	Scope	103
C10.2	Peer Review	103
C10.3	Site Perimeter Components	103
	C10.3.1 Performance Qualification by Full-Scale Testing.	103
	C10.3.2 Performance Qualification by Analysis and Design	103
C10.4	Building Structural Components	103
	C10.4.1 Performance Qualification by Full-Scale Testing.	103
C10.5	Shielding Structures	104
	C10.5.1 Performance Qualification by Full-Scale Testing.	104
	C10.5.2 Performance Qualification by Analysis and Design	104
C10.6	Building Façade Components	104
	C10.6.1 Glazing and Glazing Systems.	104
	C10.6.2 Doors	104
C10.7	Building Nonstructural Components	104
	C10.7.1 Performance Qualification by Full-Scale Testing.	104
	C10.7.2 Performance Qualification by Analysis and Design	104
INDEX		107

This page intentionally left blank

FOREWORD

The material presented in this publication has been prepared in accordance with recognized engineering principles. This Standard and Commentary should not be used without first securing competent advice with respect to their suitability for any given application. The publication of the material contained herein is not intended as a representation of warranty on the part of the American Society of Civil Engineers or of any person named herein, or 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 for such use.

The intent of the committee that prepared this standard was to present current practice in the analysis and design of structures for blast resistance. To accomplish that goal, the committee called upon its collective experience in the practice of blast resistant design, and consulted persons not on the committee. As such, this is a consensus document and does not reflect the specific practice of any individual.

This is the first edition of this standard. Its need had been identified in advance of the events of September 11, 2001. In

fact, key individuals of the original nucleus of the committee and the Structural Engineering Institute (SEI) were on a conference call to discuss development of this standard as the events of that day began to unfold. In the months following SEI's announcement that a committee would be formed to prepare this standard, numerous experts stepped forward to volunteer for the effort. Hence, this standard represents approximately ten years of dedicated work by a knowledgeable committee.

The process started with subcommittees preparing "white papers" covering the information to be included in the standard. Once circulated for comment, those documents were reformatted into the first drafts of chapters of the mandatory and commentary sections of the standard. Then, throughout the development process the full committee reviewed and balloted numerous drafts of the standard. At each ballot cycle, subcommittees proposed resolutions for members' comments, ultimately leading to the full committee's approval of the text in this volume.

This page intentionally left blank

ACKNOWLEDGMENTS

Donald Dusenberry, P.E., F.ASCE, *Chair*
Jon Schmidt, P.E., M.ASCE, *Vice-Chair*
Paul Hobelmann, P.E., M.ASCE, *Secretary*

Chapter Leaders

Jon Schmidt, P.E., M.ASCE, Chapters 1, 2, and 3
Paul Mlakar, Ph.D., P.E., Dist.M.ASCE, Chapter 4
Lorraine Lin, Ph.D., P.E., M.ASCE, Chapters 5 and 8
Robert Smilowitz, Ph.D., P.E., M.ASCE, Chapters 6 and 7
Steven Smith, Ph.D., P.E., M.ASCE, Chapter 9
Andrew Whittaker, Ph.D., S.E., M.ASCE, Chapter 10

John Abruzzo, P.E., M.ASCE
Farid Alfawakhiri, Ph.D., P.E., M.ASCE
Iyad Alsamsam, Ph.D., P.E., S.E., M.ASCE
Charles Baldwin, P.E., M.ASCE
Curt Betts, P.E., M.ASCE
Scott Campbell, Ph.D., P.E., M.ASCE
Charles Carter, M.ASCE
Edward Conrath, P.E., M.ASCE
W. Corley, Ph.D., P.E., NAE,
Dist.M.ASCE
Marvin Criswell, Ph.D., P.E., F.ASCE
Juan Carlos Esquivel, P.E., M.ASCE
Molly Evans, P.E., M.ASCE
David Fanella, Ph.D., P.E., F.ASCE
Simon Foo, P.E., M.ASCE

Andrew Hart, Aff.M.ASCE
Owen Hewitt, P.E., M.ASCE
Jennifer Holcomb, P.E., M.ASCE
Rolfe Jennings, P.E., M.ASCE
William Johnson, P.E., F.ASCE
Kim King, A.M.ASCE
Francis Laux, R.A., Aff.M.ASCE
Joel Leifer, P.E., M.ASCE
H. S. Lew, Ph.D., P.E., F.ASCE
Anatol Longinow, Ph.D., P.E., M.ASCE
Timothy Mays, A.M.ASCE
Douglas Merkle, Ph.D., P.E., F.ASCE
George Olive, M.ASCE
Glen Pappas, Ph.D., P.E., S.E., M.ASCE
Paul Perrin, P.E., M.ASCE

Keith Quick, P.E., M.ASCE
Ralph Rempel, P.E., M.ASCE
Hani Salim, A.M.ASCE
Karnik Seferian, P.E., M.ASCE
Joseph Smith, A.M.ASCE
Young Sohn, P.E.
Harold Sprague Jr., P.E., F.ASCE
Douglas Taylor
Andrew Thompson, P.E., M.ASCE
Gregory Varney, P.E., M.ASCE
Johnny Waclawczyk Jr., P.E., M.ASCE
Kenneth Walerius, P.E., M.ASCE
D. Erich Weerth, P.E., M.ASCE
William Zehrt Jr., P.E., M.ASCE
Mohamad Zineddin, M.ASCE

This page intentionally left blank

Chapter 1 GENERAL

1.1 SCOPE

This voluntary Standard provides minimum planning, design, construction, and assessment requirements for new and existing buildings subject to the effects of accidental or malicious explosions, including principles for establishing appropriate threat parameters, levels of protection, loadings, analysis methodologies, materials, detailing, and test procedures. However, this Standard is not applicable for the mitigation of potential accidents involving ammunition or explosives during their development, manufacturing, testing, production, transportation, handling, storage, maintenance, modification, inspection, demilitarization, or disposal.

This Standard is intended to supplement and not supersede the requirements of the governing building code and other applicable standards and laws. The omission of any specific material or system does not necessarily preclude its use in accordance with this Standard, as long as all applicable provisions are satisfied. This Standard does not prescribe requirements or guidelines for the mitigation of progressive collapse or other potential postblast behavior.

1.2 DEFINITIONS

The following definitions apply to the provisions of the entire Standard.

Aggressor: A person or organization that may initiate an attack against an asset.

Approved: Acceptable to the authority having jurisdiction.

Asset: A unit or collection of people or property that requires protection.

Attack: An attempt by an aggressor to cause the loss or compromise of an asset or group of assets.

Authority Having Jurisdiction: The organization, political subdivision, office, or individual charged with the responsibility of administering and enforcing the provisions of this Standard. It shall be permissible for the Authority Having Jurisdiction to be established by contractual agreement, when appropriate.

Average Strength Factor, ASF: A factor applied to nominal material strengths to account for the difference between the specified minimum and expected actual values. Also known as a **Static Increase Factor, SIF**.

Balanced Design: Controlled failure of a system with an established hierarchy of component failures, where connections are designed for the maximum strength of the connecting components and members supporting other members are designed for the maximum strength of the supported members. For window systems, the glazing shall fail before all other components.

Blast: Synonym for **Explosion**.

Building Envelope: Exposed elements on the exterior of the building, including (but not limited to) exterior walls, roofs, fenestration, exterior columns, spandrel and cantilever beams, and the exposed underside of occupied floors.

Buildings: Structures, usually enclosed by walls and a roof, constructed to provide support or shelter for an intended occupancy.

Compression Element: An element that carries an axial compression load greater than 10% of its axial compression strength. The factored load due to effects other than blast shall be determined in accordance with Section 3.5.3, and the effective strength shall be determined in accordance with Sections 3.5.1 and 3.5.2.

Connection: The means by which two or more elements are attached to each other, such as a beam to a column, a wall to another wall, a wall to a slab, etc. Steel connections are assemblies that include, but are not limited to, welds, bolts, rivets, angles, and plates. Reinforced concrete connections are often integral, consisting of the concrete and the reinforcement at the end of one element and extending into the other.

Consequence Factor: A numerical measure of the relative impact of the loss or compromise of a specific asset within a building, including its occupants, often expressed in terms of quantity or cost.

Constrained Fragment: A secondary fragment whose velocity in an airblast is reduced by the amount of energy required to tear it from its connected structural element.

Daylight Installation: A retrofit method for existing windows where security window film is applied to the interior vision surface of the glass without any additional attachment at the edges.

Dead Load, *D*: The weight of materials of construction incorporated into the building including, but not limited to, walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding, and other similarly incorporated architectural and structural items, and fixed service equipment including the weight of cranes.

Design Basis Threat: The explosive type and charge size for which the building is intended to provide a specified level of protection.

Diagonal Tension Shear: Shear associated with the flexural response of an element and the formation of diagonal cracks in reinforced concrete or masonry sections.

Direct Shear: Shear associated with the nearly instantaneous reaction force at the interface between connected elements in response to blast loading.

Ductile Flexural Element: An element that develops its plastic moment capacity and is capable of reliably sustaining deformation at or above this load level.

Ductility: A measure of the capability of an element, a cross section, or a connection to undergo inelastic deformation without significant loss of strength.