ASCE STANDARD

ASCE/SEI 59–11

Blast Protection of Buildings

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

ASCE

SEI ASCE STRUCTURAL ENGINEERING INSTITUTE

American Society of Civil Engineers

Blast Protection of Buildings

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

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

SEI
ASCE
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.

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

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.

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

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.