

American Society of Civil Engineers

Tensile Membrane Structures

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



Library of Congress Cataloging-in-Publication Data

Tensile membrane structures.

p. cm. – (ASCE standard)

“ASCE/SEI55-10.”

Includes bibliographical references and index.

ISBN 978-0-7844-1097-4 (alk. paper)

1. Tensile architecture—Standards—United States. 2. Lightweight construction—Standards—United States. 3. Roofs, Fabric—Standards—United States. 4. Synthetic fabrics—Standards—United States. 5. Structural frames—Standards—United States.

I. American Society of Civil Engineers.

TA663.T45 2010

624.1—dc22

2010029294

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 © 2010 by the American Society of Civil Engineers.

All Rights Reserved.

ISBN 978-0-7844-1097-4

Manufactured in the United States of America.

STANDARDS

In 2003, 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 19-96 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 33-01 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/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 Dispersion 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 48-05 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

FOREWORD

The material presented in this standard has been prepared to be 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) and its Structural Engineering Institute (SEI) gratefully acknowledge the devoted efforts of the Tensile Membrane Structures Standard Committee of SEI. This committee comprises individuals from many backgrounds, including architecture, consulting engineering, research, construction, education, government,

design, and private practice. This standard was prepared through ASCE's consensus standards development process in compliance with the rules and procedures of ASCE's Codes and Standards Committee (CSC). ASCE's standards development process is accredited by the American National Standards Institute (ANSI).

TENSILE MEMBRANE STRUCTURES STANDARD COMMITTEE ROSTER

Edward M. DePaola—Co-Chairman
Louis F. Geschwindner—Co-Chairman
Harry B. Daugherty—Vice Chairman
Ronald E. Shaeffer—Secretary
Tore O. Arnesen
John R. Battles
Peter J. Bos
Frank Bradenburg
Richard R. Bradshaw
Dirk Cos
Marcel Dery
William E. Fitch

Ramon E. Gilsanz
Paul A. Gossen
Kris P. Hamilton
Michael W. Ishler
Gary Moore
Bill Murrell
Wayne Rendely
Donald R. Smith
Gary E. Sutryn
David P. Thompson
Robert F. Wieber

CONTENTS

Standards	iii
Foreword	v
Acknowledgements	vii
Tensile Membrane Structures Standard Committee Roster	ix
1 General	1
1.1 Scope	1
1.2 Definitions	1
1.3 Design Documents	2
1.4 Field Observation	3
1.5 Alternate Designs	3
1.6 References	3
2 Membrane Materials	5
2.1 General	5
2.2 Testing Qualifications	5
2.3 Physical Testing	5
2.4 Physical Properties	6
2.5 Membrane Classification and Fire Performance	6
2.6 Seams	6
2.7 Cables and Reinforcing	7
3 Connections	9
4 Design	11
4.1 Notation	11
4.2 Loads	11
4.3 Considerations for Design and Analysis	12
4.4 Member Proportioning	12
4.5 Load Combinations	13
4.6 Component Resistance	13
4.7 Anchorage	14
5 Fabrication and Erection	15
5.1 Fabrication	15
5.2 Erection	15
Appendix A Special Provisions	17
Appendix B A Procedure for Determining Modulus of Elasticity	23
Bibliography	27

Commentary	31
C.1 General	31
C.2 Membrane Materials	33
C.3 Connections	35
C.4 Design	35
C.5 Fabrication and Erection	38
C.A Appendix A Special Provisions	38
Index	41

1

GENERAL

1.1 SCOPE

1.1.1 This standard provides minimum criteria for the design and performance of membrane-covered cable and rigid member structures, including frame structures, collectively known as tensile membrane structures, including permanent and temporary structures as defined herein. The requirements of this standard shall apply whether the tensile membrane structure is independent of or attached to another structure. This standard does not apply to air-supported or air-inflated structures.

1.1.2 This standard is applicable to all tensile membrane structures as follows:

- a. temporary structures with a plan area greater than 1,000 ft² (100 m²) or with any membrane span exceeding 10 ft (3 m) or
- b. permanent structures with a plan area greater than 225 ft² (22.5 m²), regardless of span.

1.1.3 This standard is applicable to tensile membrane structures erected under the requirements of the legally adopted building code of which this standard forms a part. In areas without a legally adopted building code, this standard defines minimum acceptable standards of design and construction practice.

1.1.4 This standard supplements the building code and shall govern in all matters pertaining to design, construction, and material properties. This standard may be used in the absence of a building code or where the building code does not adequately address membrane structures.

1.1.5 Elements of a tensile membrane structure not governed by this standard (e.g., structural steel, cables, timber, aluminum, or concrete) shall be proportioned in accordance with their respective standards.

1.2 DEFINITIONS

The following definitions apply in this standard:

Air-inflated structure—A membrane structure with a shape that is maintained by air pressure acting within cells or tubes enclosing all or part of the occupied space.

Air-supported structure—A membrane structure that encloses an occupied space and has a shape that is maintained by air pressure acting within the occupied space.

Anchorage—A device used to secure a membrane or cable to a support.

Authority having jurisdiction—The organization, political subdivision, office, or individual charged with responsibility of administering and enforcing the provisions of this standard.

Biaxial stress—Stresses taken simultaneously along two concurrent orthogonal directions, usually warp and fill.

Cable—A flexible linear or curvilinear element acting in tension. Cable may be wire rope, strand, or web.

Compensation (and decompensation)—Adjustment during patterning of membrane panel dimensions to allow for stretching of the material as required to achieve the desired initial prestress and geometry.

Design strength—The strength determined by multiplying the ultimate strength by one or more strength reduction factors.

Effective membrane breaking strength—The strength of the membrane or seam, whichever is less.

Effective prestress—The prestress remaining in the structure after all losses, including long-term losses, have occurred.

Fabric—A two-dimensional cloth made up of yarns or slit tapes that may be impregnated with a matrix that binds them together. The yarns may be woven or laid. The fabric is frequently coated or laminated.

Factored load—The product of the nominal loads and load factors used to proportion members by strength design.

Fibers—Lengths of threads of a material. When twisted together, they make a yarn.

Fill—The yarns that are placed in the narrow direction of the fabric as it is manufactured (also known as Weft).

Film—An unreinforced plastic. Film does not contain fibers or yarn.

Frame-supported structure—A membrane structure consisting of a series of arches or frames where the membrane is pretensioned primarily uniaxially and