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Tensile Membrane Structures

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PREFACE

This version of ASCE 55 improves on the previous edition in three ways:

1. The inclusion of load resistance factor design (LRFD) and allowable stress design (ASD) load combinations;
2. The inclusion of air-supported membrane structures as Chapter 6 of this standard, which now replaces Standard ASCE 17-96, *Air-Supported Structures*; and
3. Providing a single document that deals with conventional tensile membrane structures, frame-covered membrane structures, and air-supported tensile membrane structures.

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Those individuals who served on the ASCE 55 Tensile Membrane Structures Committee are:

Voting Members

Maqsood Ahmed, *Lead Author, Chapter 5*
Tore Arneson, *Lead Author, Chapter 3*
Peter Bos, *Secretary & Coauthor, Appendix A*
Steven Brown, *Lead Author, Chapter 2*
David Campbell, *Lead Author, Chapter 4*
Dirk Cos
Edward M. DePaola, P.E., SECB, F.SEI, *Chair*
Bill Fitch, *Coauthor, Appendix A*
Ramon Gilsanz
Al Gonzalez
Steven Kiss
Tom McCoy
Pedro Munoz
Wayne Rendely
Ron Shaeffer, *Lead Author, Chapter 1*
Tom Soehngen, *Lead Author, Chapter 6*
Gary Sutryn
David Thompson
Sue Uhler
Mark Waggoner

Associate Members

Paul Gossen
Kris Hamilton
Mike Ishler
Bill Murrell
Elizabeth Murrell

Member Emeritus

Richard A. Bradshaw, *Lead Author, Appendix B*

CHAPTER 1
GENERAL

1.1 SCOPE

This standard provides minimum criteria for the analysis, design, and performance of membrane-covered cable and rigid member structures, including frame supported structures and air-supported 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-inflated structures as defined in Section 1.2, Definitions. This standard does not apply to films as defined in Section 1.2.

This standard is applicable to all tensile membrane structures as described: Temporary structures with a plan area greater than 1,000 ft^2 (93 m^2) or with any membrane span exceeding 10 ft (3 m), and permanent structures with a plan area greater than 225 ft^2 (21 m^2), regardless of span.

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 geographical areas without a legally adopted building code, this standard defines minimum acceptable standards of design and construction practice.

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

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 Pressures—Pressures that are identified as

- Maximum internal pressure: the greatest pressure that the inflation system is capable of developing within the structure
- Maximum operating pressure: the greatest pressure permitted with immediate and continuous supervision of the pressure control system
- Minimum operating pressure: the lowest pressure at which the structure is designed to operate
- Normal operating pressure: the range of operating pressures specified when special methods are not necessary to accommodate unusual loads
- Residual pressure: the pressure used to determine the deflation index, D_i.

Air-inflated Structure—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—Membrane structure that encloses an occupied space and has a shape that is maintained by air pressure acting within the occupied space.

Anchorage—Device used to secure a membrane or cable to a support or a supporting system.

Authority Having Jurisdiction—An organization, political subdivision, office, or individual charged with responsibility of administering and enforcing the provisions of this standard and those of the building code.

Biaxial Stress—Stress occurring simultaneously along two concurrent orthogonal directions, usually warp and fill.

Cable—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 that allows for stretching of the material as required to achieve the desired initial prestress and geometry.

Deflation Index—Calculated value used to ensure a margin of safety for emergency egress from an air-supported structure.

Design Strength—Strength determined by multiplying ultimate strength by one or more strength-reduction factors.

Effective Membrane Breaking Strength—Ultimate strength of the membrane or seam, whichever is less.

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

Fabric—Cloth produced by interlacing or warp knit, yarns, fibers, or filaments that may be woven or laid, and may be impregnated with a matrix that binds them together. The fabric is frequently coated or laminated.

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

Fan—Air-moving device, including axial, centrifugal, or propeller blowers.

Fibers—Individual threads of a material that can be spun into a yarn or made into a fabric by various methods including weaving, knitting, braiding, felting, and twisting.

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

Film—Unreinforced sheet that does not contain fibers or yarn.

Frame-supported Membrane Structure—Membrane structure supported by a rigid framework of which the membrane may or may not be a part, or a supplement to the primary structural system.

Inflation System—All necessary components of a mechanical system required for inflation and operation of an air-supported structure. This may include but are not limited to fans, motors, backdraft dampers, relief dampers, heaters, housings, ducts not

fully contained in the pressurized space, standby power, and controls.

Life-cycle Factor—Strength-reduction factor included to account for the fact that the strength of some materials decreases with time because of the effects of continuous loading, environmental exposure, and aging.

Load Factor—A number, usually greater than 1.0, applied to loads to increase the effects of the loads on the structure to account for uncertainties in the load estimation.

Lot—Unit of production that is taken for sampling or statistical examination, having one or more common properties.

Material Manufacturer—Business entity whose primary purpose is the production of membrane roll-goods that are subject to membrane fabricator testing requirements as referenced herein, where membrane assemblies are produced for a specific project. See Membrane Fabricator.

Membrane—Flexible, coated, or laminated structural fabric or film that supports the imposed loads and transmits them to the supporting structure. For the purpose of this standard, forces on the membrane result only in tension or shear in the plane of the membrane.

Membrane Component—Material required to resist prestress and all applied loads that are not subject to requirements of other design standards, or where the applicable design standards do not apply. Materials include but are not limited to membrane, nonmetallic cables and rope, and web made from nonmetallic material.

Membrane Fabricator—Business entity whose primary purpose is the production of membrane assemblies using roll-goods supplied by a material manufacturer for tensile membrane structures. See Material Manufacturer.

Membrane Liner—Interior fabric or film used for decorative, acoustic, thermal insulation, or other nonstructural purposes.

Membrane Tear Strength—Force required to initiate or propagate a tear in the membrane under specified conditions.

Membrane Tensile Strength—Strength established by rational methods and applicable standards. For fabric, this is the strip tensile strength, as determined in accordance with ASTM D4851.

Minimum Test Value—Published value that exceeds the 95% confidence level of all samples tested.

Nominal Strength—Strength of a member before applying any strength reduction factors.

Patterning—Process of determining how to cut the pieces of two-dimensional flat fabric so that when joined together and prestressed, they produce a three-dimensional structure.

Permanent Structure—Structure that is intended to remain in its erected position and location for a period of 180 days or more.

Prestress—Stress that is induced in the structure for the purpose of defining the geometry and initial state of the structure.

Roll—Unit within a lot based on weight, width, and material length.

Scrim—Fabric used as the base cloth in the production of coated and laminated membranes.

Seam—Joining of two or more pieces of membrane material.

Sectionalizing—Making of a field splice, often used to connect large sections of membrane.

Selvage—Self-finished edge of fabric that holds it in place from unraveling or fraying.

Service Life—Usable life of a structure, usually dependent on the activities within the structure and external environmental conditions.

Service Load—Any load anticipated to be imposed on the structure to which no factors have been applied.

Strength Reduction Factor—A factor (usually less than 1.0) that is applied to the strength of a material to account for uncertainties in the material properties or loading conditions.

Stress—For support structure and anchorages, this is force per unit area; for membranes, it is force per unit length.

Support Structure—Arches, trusses, beams, columns, cables, foundations, and other nonmembrane elements.

Tensile Membrane Structure—Structure with a shape that is determined by tension in the membrane and the geometry of the support structure. Typically, the structure consists of flexible elements (e.g., membrane and cables), nonflexible elements (e.g., struts, masts, beams, and arches), and the anchorage (e.g., supports and foundations). For the purposes of this standard, tensile membrane structures also include frame-supported structures and air-supported structures.

Uniaxial Stress—Stress applied parallel to one axis (usually the warp or fill) where no stress is applied in the orthogonal direction.

Warp—Set of yarns that runs lengthwise and parallel to the selvage.

Web—Belt of woven or braided fabric.

Weft—See Fill.

Yarn—Generic term for a continuous strand of textile fibers, filaments, or material suitable for knitting, weaving, or otherwise forming a textile fabric.

1.3 DESIGN DOCUMENTS

Design drawings and specifications shall, at a minimum, show

- Name and date of issue of code and supplement to which design conforms
- All loads used in the design
- Reactions
- Specified strength of fabric and seams for each part of a structure
- Type of membrane
- Size and location of all structural elements
- Maximum cable forces
- Magnitude and location of prestress forces
- Directions of warp and fill
- Type and location of any mechanical connections and the maximum forces acting on them
- Intended period of erection and anticipated environmental conditions based on clear designs for temporary or seasonal structures
- Schedule of required maintenance.

1.4 FIELD OBSERVATION

1.4.1 Qualifications. Construction shall be observed periodically throughout the various work stages by the engineer or architect of record or by a representative responsible to that engineer or architect and as required by the authority having jurisdiction.

1.4.2 Records. Construction records shall, at a minimum, include the following:

- Verification that the fabric is as specified
- Construction and removal of temporary supports
- Placement of membrane
- Sequence of erection and connection of all members
- Tensioning of prestressing elements
- Identification of any significant construction loadings on the structure
- Documentation of any defects, flaws, or repairs.

1.5 ALTERNATE DESIGNS

The provisions of this standard are not intended to limit the appropriate use of materials, systems, equipment, methods of design, or construction procedures not described specifically in this standard, provided that such alternate design methods and construction procedures are conducted by a design professional specially qualified in the specific methods applied, and provided that such techniques demonstrate a level of safety and performance consistent with the requirements of Chapter 4. Structures and structural components that are not amenable to analysis using generally accepted theories may be designed by

- Evaluation of full-scale structure(s)
- Evaluation of a full-scale prototype through tests
- Studies of model analogs.

1.6 REFERENCES

The following standards are referred to in this document:

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NFPA 72. (2016). "National fire alarm and signaling code."

NFPA 701. (2015). "Standard methods of fire tests for flame propagation of textiles and films."

NFPA 780. (2015). "Standard for the installation of lightning protection systems."