



SECTION 13 31 23
TENSIONED FABRIC STRUCTURES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Section includes a tensioned fabric canopy system as shown on Drawings and specified in this Section.
2. Architect's drawings indicate design intent with respect to sizes, shapes, and configurations of the tensioned fabric canopy. Provide all components and accessories required for complete tensioned fabric canopy system, whether or not specifically shown or specified.
3. The tensioned fabric structure will assume bolted/pinned connections for field assembly. No field welding will be permitted.

B. The tensioned fabric structure Subcontractor shall be responsible for the structural design, detailing, fabrication, supply, and installation of the Work specified herein. The intent of this specification is to establish in the first instance an undivided, single-source responsibility of the Subcontractor for all of the foregoing functions.

C. All element sizes, material strengths, forces and quantities shown on the contract documents are to be taken as a developed concept. Final structural analysis and design are the responsibility of the subcontractor. The subcontractor is responsible at the time of bid to determine any additional costs related to their design and member sizing for the fabric roof.

D. Subcontractor's Work shall include the structural design, supply, fabrication, shipment, and erection of the following items:

1. The architectural membrane as indicated on the drawings and in these specifications.
2. Cables and fittings.
3. Perimeter, catenary, and sectionalized aluminum clamping system.
4. Structural steel, including masts, trusses, struts, and beams as indicated on the drawings.
5. Fasteners and gasketing.

E. Related Requirements:

1. Related Documents: Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
2. Division 03 Section "Cast-in-Place Concrete" for concrete footings for posts of tensioned fabric structure.
3. Division 05 Sections "Structural Steel Framing" and "Architecturally Exposed Structural Steel" for steel structure supporting tensioned fabric structure.

- F. This Project is a US Green Building Council LEED™ – CI project:
1. Select materials to maximize use of recycled steel.
 2. Select locally or regionally fabricated products wherever possible.

1.2 REFERENCES

A. Definitions:

1. Tensioned Fabric Structure: Cable and/or frame supported tensioned membrane-covered fabric structure; incorporating a fabric with low elongation characteristics under tension and capable of an anticlastic configuration. Fabric structures in which fabric is applied as flat or mono-axially curved configurations are not acceptable.

B. Reference Standards: Except as otherwise shown or noted, all work shall comply with the requirements of the following codes and standards:

1. American Institute of Steel Construction (AISC).
 - a. Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings.
 - b. Code of Standard Practice for Steel Buildings and Bridges.
 - c. Specification for Structural Steel Buildings – Allowable Stress Design and Plastic Design.
 - d. Specification for Allowable Stress Design of Single-angle Members.
 - e. Seismic Provisions for Structural Steel Buildings.
2. American Society of Civil Engineers.
 - a. ASCE 19: Structural Applications of Steel Cables for Buildings.
3. American Society of Testing and Materials (ASTM).
 - a. ASTM A586: Standard Specifications for Zinc-Coated Steel Structural Strand.
 - b. ASTM A603: Standard Specifications for Zinc-Coated Steel Structural Wire Rope.
 - c. ASTM D4851-88: Standard Test Methods for Coated and Laminated Fabrics for Architectural Use.
 - d. ASTM E84: Standard Test Method for Surface Burning Characteristics of Building Materials.
 - e. ASTM E108: Standard Test Methods for Fire Test and Roof Coverings.
 - f. ASTM E136: Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 degrees C.
 - g. ASTM C423: Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method.
 - h. ASTM E424: Standard Test Method for Solar Energy Transmittance and Reflectance of Sheet Materials.
4. American Welding Society (AWS).
 - a. AWS D1.1: Structural Welding Code.
 - b. AWS 2.4: Symbols for Welding and Nondestructive Testing.
5. Aluminum Association
 - a. Specifications for Aluminum Structures.

6. National Fire Protection Association (NFPA).
 - a. NFPA 701: Standard Methods of Fire Tests for Flame Propagation of Textiles and Films.
7. Steel Structures Painting Council (SSPC).
 - a. Steel Structures Painting Manual, Volumes 1 and 2.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include styles, material descriptions, construction details, fabrication details, dimensions of individual components and profiles, hardware, fittings, mounting accessories, features, and finishes for tensioned fabric structures.
2. Include rated capacities, light transmissions, and operating characteristics of furnished specialties and accessories.

B. LEED™ Submittals:

1. Product Data for Credit MR 4: For products having recycled content, documentation indicating percentages by weight of post-consumer and pre-consumer recycled content. Include statement indicating cost for each product having recycled content.
2. Product Certificates for Credit MR 5.1[and Credit MR 5.2]: For products and materials required to comply with requirements for regionally manufactured materials. Include statement indicating cost for each regionally manufactured material.
 - a. Include statement indicating location of manufacturer and distance to Project for each regionally manufactured material.

C. Design Drawings:

1. Include plans, elevations, sections, mounting heights, and frame assembly details.
2. Preliminary member sizes with wall thickness TBD.
3. Preliminary footing layout and foundation design with final depth TBD.
4. Show intended fabric attachment hardware and details.
5. Identify direction, details and locations of fabric seams.
6. Show details of fabric membrane dimensions including length of spans, sag in curvature and actual shaded area.

D. Engineered Drawings (submit after Design Drawings have been approved):

1. Calculations with Wet Stamp seal of a Professional Engineer with a license in the same state as the project location.
2. Engineering Drawings with Wet Stamp seal of a Professional Engineer with a license in the same state as the project location.
3. Include plans, elevations, sections, mounting heights, and frame assembly details.

4. Provide frame member sizes and required wall thicknesses.
 5. Identify all welding requirements.
 6. Detail all bolted and/or pin connections for frame assembly.
 7. Identify required sizes of bolts, pins, plates and tubing.
 8. Verify the fabric meets minimum engineering requirements.
 9. Detail fabric attachment methods and identify thickness of all membrane plates, clamps and other attachment components.
 10. Call out all cable sizes and pretension requirements.
 11. Submit anchor-bolt plans before foundation work begins. Include location, diameter, and projection of anchor bolts required to attach the tensioned fabric structures to foundation. Indicate column reactions at each location.
- E. Samples for Initial Selection: Electronic file of available frame finish colors.
- F. Samples for Verification: For the following:
1. Fabric: Qty (3) 8 ½" x 11" samples of fabric as selected by the architect.
 2. Frame Finish: Qty (3) Sample chips, not less than 2" x 3" in size.
- G. Provide a Schedule of Values within (2) weeks of project award.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For Installer, Subcontractor, and professional engineer.
- B. Welding certificates.
- C. Sample Warranty: For fabric warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For tensioned fabric structures to include in operation and maintenance manuals.
 1. Include the following:
 - a. Methods for maintaining tensioned fabric structure fabrics and finishes.
 - b. Precautions about cleaning materials and methods that could be detrimental to fabrics, finishes, and performance.

1.6 QUALITY ASSURANCE

- A. Subcontractor Qualifications: Shop that employs skilled workers who custom-fabricate tensioned fabric structures similar to those required for this Project and whose products have a record of successful in-service performance.
 1. Subcontractor must be an active member of Industrial Fabric Association International (IFAI) and Fabric Structures Association (FSA).

2. Subcontractor's responsibilities include fabricating and installing tensioned fabric structures and providing professional engineering services needed to assume engineering responsibility.
 3. Subcontractor's engineering services must utilize Finite Element Analysis software that performs fabric form finding and takes into account fabric material properties and prestress characteristics.
 4. Subcontractor must have proven record of at least (10) successful projects of similar size and similar specified fabric material.
 5. Subcontractor must have been in continuous operation as a professional tensioned fabric structure manufacturer for minimum of (15) years prior to contract.
 6. Subcontractor must be an American owned company.
 7. Subcontractor must have an in-house Made-in-America manufacturing facility for both frame and fabric membrane components.
 8. Subcontractor must be a Los Angeles approved certified welder.
 9. Subcontractor must have a Green rating with Dunn & Bradstreet for timely payment to vendors.
 10. Subcontractor must have in-house installers with 10-hour OSHA training certificates.
- B. Installer Qualifications: Fabricator of products.
- C. Welding Qualifications: Qualify procedures and personnel according to the following:
1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."

1.7 FIELD CONDITIONS

- A. Weather Limitations: Proceed with installation only when existing and forecasted weather conditions permit installation of tensioned fabric structure in exterior locations to be performed according to Subcontractors' written instructions and warranty requirements.
- B. Field Measurements: Where tensioned fabric structure installation is indicated to fit to other work, verify dimensions of other work by field measurements before fabrication and indicate measurements on Shop Drawings. Allow clearances for fenestration operation throughout the entire operating range. Notify Architect of discrepancies. Coordinate fabrication schedule with construction progress to avoid delaying the Work.

1.8 WARRANTY

- A. Special Warranty: Manufacturer and Subcontractor agree to repair or replace components of tensioned fabric structures that fail in materials or workmanship within specified warranty period of one year from the date of Substantial Completion.
 1. Failures include, but are not limited to, the following:
 - a. Structural failures including framework.
 - b. Deterioration of fabric including seam failure.
 - c. Deterioration of metals, metal finishes, and other materials beyond normal weathering.

2. Warranty Period, Fabric: Reference the manufacturer's limited warranty for the specified fabric manufacturer and product.
3. Warranty Period, Cables, Securement Devices and Accessories: One year from date of Substantial Completion

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Basis-of-Design: Subject to compliance with requirements, provide the tensioned fabric structures designed, engineered, fabricated and installed by the following:
 1. Acceptable Manufacturer: Eide Industries, Inc. located at: 16215 Piuma Avenue, Cerritos, CA 90703; Toll Free Tel: 800-422-6827; Tel: 562-402-8335; Fax: 562-924-2233; Email: ajuarez@eideindustries.com; Web: www.eideindustries.com or www.tensionstructures.com.
 2. Or approved equal. Subcontractor must meet all minimum requirements as outlined in item 1.6 QUALITY ASSURANCE of this section and show written proof for each item listed to become an approved equal.
 3. Substitution requests must be submitted by a Prime Bidder, minimum of (10) days prior to bid date. Any approved equals shall be issued by addendum only, prior to the bid date.
 4. Applicant for approve equal must submit engineering analysis along with pricing. Analysis must include:
 - a. Finite Element Analysis under various load cases
 - b. Fabric form finding of membrane
 - c. Adequate membrane gradient under load displacement to allow water runoff
 - d. Frame member and cable sizing
 - e. Footing reaction loads
- B. Source Limitations: Obtain tensioned fabric structures from single source from single Subcontractor.

2.2 DESCRIPTION

- A. General: Provide a tensioned fabric structure system that complies with requirements specified herein by testing the Subcontractor's corresponding membrane system in accordance with the indicated test methods.
- B. Regulatory Requirements: Provide tensioned fabric canopy system complying with requirements and limitations of authorities having jurisdiction that are within Contractor's control.
 1. Building Code Criteria: The tensioned fabric structure shall comply with the International Building Code, latest edition.
 2. Comply with local building codes and respective loading criteria for Snow Loads, Live Loads, Dead Loads, Wind Speed, and Seismic Loads.
 3. Life Safety: Tensioned fabric structure shall be detailed so that no life safety issue is created in the event of a loss of a part of the membrane. The tensioned fabric structure shall not rely on the membrane for structural stability.

2.3 PERFORMANCE / DESIGN CRITERIA

- A. Delegated Design: Engage a qualified professional engineer to design tensioned fabric canopy system. Delegated design engineering requirements include, but are not limited to, the following:
1. Prepare structural design drawings defining the precise interface geometry determination, reaction loads imposed on structural steel framing, anchoring loads, connection details, interfaces, and seam layouts.
 2. Structural calculations for the tensioned fabric canopy system shall include:
 - a. Large deflection numerical shape generation that will insure a stable, uniformly stressed, three dimensionally curved shape that is in static equilibrium with the internal prestress forces and is suitable to resist all applied loads.
 - b. Large deflection finite element method structural analysis of the membrane system under all applicable wind and seismic loads.
 - c. Connection design including bolt, weld and ancillary member sizing.
 - d. Biaxial fabric test specification, interpretation and fabric compensation determination.
 - e. Accurate generation of the two-dimensional compensated fabric templates required to generate the three-dimensional equilibrium shape.
- B. In engineering tensioned fabric canopy system fittings and accessories to withstand structural loads indicated, determine allowable design working stresses of railing materials based on the following:
1. Steel: 72 percent of minimum yield strength.
 2. Stainless Steel: 60 percent of minimum yield strength.
 3. Aluminum: The lesser of minimum yield strength divided by 1.65 or minimum ultimate tensile strength divided by 1.95.
- C. Structural Performance: Tensioned fabric canopy system shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated according to ASCE/SEI 7:
1. Wind Loads: To be determined by Subcontractor's Engineer of Record.
 2. Live Loads: To be determined by Subcontractor's Engineer of Record.
 3. Snow Loads: To be determined by Subcontractor's Engineer of Record.
 4. Seismic Loads: To be determined by Subcontractor's Engineer of Record.
- D. General: In engineering railings to withstand structural loads indicated, determine allowable design working stresses of railing materials based on the following:
1. Aluminum: The lesser of minimum yield strength divided by 1.65 or minimum ultimate tensile strength divided by 1.95.
 2. Copper Alloys: 60 percent of minimum yield strength.
 3. Stainless Steel: 60 percent of minimum yield strength.
 4. Steel: 72 percent of minimum yield strength.

- E. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes.
 - 1. Temperature Change: 120 deg F, ambient; 180 deg F, material surfaces.
- F. Control of Corrosion: Prevent galvanic action and other forms of corrosion by insulating metals and other materials from direct contact with incompatible materials.

2.4 CANOPY FABRIC MATERIALS

- A. Product: Subject to compliance with requirements, provide fabric as called out and specified by the Architect in the bid drawings.
- B. Fire-Test-Response Characteristics: Provide canopy fabric with the fire-test-response characteristics indicated, as determined by testing identical products according to test method indicated below by UL or another testing and inspecting agency acceptable to authorities having jurisdiction:
 - 1. Flame-Resistance Ratings: Passes NFPA 701.
 - 2. Noncombustible: Passes ASTM E-136 and E-108
 - 3. Flame Spread: ASTM E-84 Class A
- C. PTFE Fabric manufacturer: The following is a list of approved PTFE fabric manufacturers for tensioned fabric structures. Reference architectural drawings for fabric call out.
 - 1. Saint Gobain (Sheerfill product line)
 - 2. Verseidag (Duraskin product line)
 - 3. Chukoh (Skytop product line)
 - 4. Taconic (Solus product line)
- D. PVC Fabric manufacturer: The following is a list of approved PVC coated Polyester fabric manufacturers for tensioned fabric structures. Reference drawings for fabric call out.
 - 1. Ferrari Textiles (Preconstraint product line)
 - 2. Seaman Corporation (Shelter-Rite product line)
 - 3. Naizil
 - 4. Hiraoka
 - 5. Mehler (Polymar product line)
- E. Fabric properties:
 - 1. Fabric thickness and tensile strength: Must meet engineering requirements with a safety factor of five.
 - 2. Color: White
 - 3. Porosity: Waterproof or 20% open Mesh

F. Fabric Substitutions

1. High Density Polyethylene (HDPE) woven mesh fabric may be substituted for non-waterproof applications only. HDPE fabric substitutions are only allowed when the architectural drawings specifically call out fabric as "Shade Fabric" or "HDPE Fabric" or "Non-waterproof Fabric" or "Fabric Mesh".
2. Acceptable manufacturers of HDPE fabrics are Polyfab, Synthesis and Monotec 370.
3. Color: To be selected from the manufacturer's range of available colors.
4. HDPE fabric membranes shall be designed to avoid contact with any PVC material.
5. Fabric shall be sewn with PTFE thread to avoid premature failure due to UV deterioration.
6. Membrane shall be sewn with a chain stitch to prevent bursting at the seams.

2.5 CANOPY FRAME, CABLES, FITTINGS AND ACCESSORIES

- A. General: Provide accessories as standard with tensioned fabric canopy system Subcontractor and as specified. Fabricate and finish accessories at the factory to greatest extent possible, by Subcontractor's standard procedures and processes. Comply with indicated profiles and with dimensional and structural requirements.
- B. Metal Surfaces, General: Provide materials with smooth surfaces, without seam marks, roller marks, rolled trade names, stains, discolorations, or blemishes.
- C. Frame material shall be constructed of cold rolled carbon steel unless otherwise specified by the architect in the bid drawings.
- D. Steel and Iron:
 1. Tubing: ASTM A 500 (cold formed) or ASTM A 513.
 2. Bars: Hot-rolled, carbon steel complying with ASTM A 29/A 29M, Grade 1010.
 3. Plates, Shapes, and Bars: ASTM A 36 or ASTM A 572 per engineering requirements.
- E. Stainless Steel (when applicable);
 1. Tubing: ASTM A 554, Grade MT 316L.
 2. Pipe: ASTM A 312/A 312M, Grade TP 316L.
 3. Castings: ASTM A 743/A 743M, Grade CF 8M or CF 3M.
 4. Sheet, Strip, Plate, and Flat Bar: ASTM A 666, Type 316L.
 5. Bars and Shapes: ASTM A 276, Type 316L.
- F. Aluminum (when applicable):
 1. Provide alloy and temper recommended by aluminum producer and finisher for type of use and finish indicated, and with strength and durability properties for each aluminum form required not less than that of alloy and temper designated below.
 2. Extruded Bars and Shapes: ASTM B 221, Alloy 6063-T5/T52.

G. Cables and Fittings shall be constructed of galvanized steel unless otherwise specified by the architect in the bid drawings:

1. All cables in contact with PTFE fabric shall be PVC coated.
2. Any cable in contact with HDPE fabric shall never have PVC coating.
3. Manufacturers: Subject to compliance with requirements, provide products by one of the following manufacturers:
 - a. John A. Batchelor Co Inc.
 - b. Jack Rueben and Sons
 - c. McMaster-Carr
 - d. Frontier Technologies
 - e. The Crosby Group
 - f. Ronstan International Inc.
4. Galvanized Cables:
 - a. Cable: 1-by-19 galvanized steel structural wire rope made from wire complying with ASTM A 603.
 - b. Cable Fittings: Connectors of types indicated or required, fabricated from hot dip galvanized steel, and with capability to sustain, without failure, a load equal to minimum breaking strength of cable with which they are used.
5. Stainless Steel Cables:
 - a. Cable: 1-by-19 wire rope made from wire complying with ASTM A 492, Type 316.
 - b. Cable Fittings: Connectors of types indicated or required, fabricated from stainless steel, and with capability to sustain, without failure, a load equal to minimum breaking strength of cable with which they are used.

H. Accessories.

1. Base Plates and Anchor Bolts.
 - a. Base plates supported on concrete shall be furnished and set on shims, leveling plates or leveling nuts. Grouting shall be by the General Contractor.
 - b. Anchor bolt locations shall be furnished by the Subcontractor and used by the General Contractor to set the bolts. The General Contractor is to carefully check the setting of the bolts to their proper position prior to placing of concrete. Anchor bolts, provided by the General Contractor, shall have two (2) nuts and washers. Damaged threads shall be repaired or be cut to permit full tightening of nuts.
 - c. Anchor bolts will have adequate thread length above concrete for the leveling nut, the base plate, the top nut, the washers and at least two full threads exposed on top. Any concrete that impedes the required thread length will be chipped away by the General Contractor prior to the installation of the frame.

I. Metal Battens for Securing Canopy Fabric to Structural Steel Frame: Extruded aluminum.

2.6 CANOPY FRAME FINISH

A. Frame Finish shall be polyester powder painted unless otherwise specified by the architect in the bid drawings.

1. Powder Coat Finish:
 - a. Commercial blast clean surface in accordance with SSPC-SP 10.
 - b. Apply primer and polyester powder coat paint to a minimum of 3 mils thick.
 - c. Color: As selected from manufacturer's available stock colors.

2. Two Part Paint Finish for corrosive environments: 5 years
 - a. Commercial blast clean surface in accordance with SSPC-SP 10.
 - b. Primer Material properties – (1) coat of Tnemec 90/97 at 2.5-3.5 mils MDFT.
 - c. Paint Material properties – (1) coat of Tnemec Series 1095 or 1096 at 3.0-5.0 mil MDFT per coat.
 - d. Minimum thickness – 5.5-8.5 mils TDFT.
 - e. Color: As selected from manufacturer's available stock colors.
 - f. 5-year warranty for gloss and color retention.

3. Two Part Paint Finish for corrosive environments: 10 years
 - a. Commercial blast clean surface in accordance to SSPC-SP 10.
 - b. Primer Material properties – (1) coat of Tnemec 90/97 at 2.5-3.5 mils MDFT.
 - c. Paint Material properties – (1) coat of Tnemec Series 750 at 3.0-5.0 mil MDFT per coat.
 - d. Minimum thickness – 5.5-8.5 mils TDFT.
 - e. Color: As selected from manufacturer's available stock colors.
 - f. 10-year warranty for gloss and color retention.

4. Galvanizing (only if architect indicates requirement on bid drawings):
 - a. Comply with either ASTM A 123/A 123M or ASTM A 153/A 153M for hot-dip galvanizing, as applicable.
 - b. Fill vent and drain holes that are exposed in the finished Work, unless indicated to remain as weep holes, by plugging with zinc solder and filing off smooth.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine structural steel framing and other substrates, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 ERECTION

- A. Proceed with installation of tensioned fabric structure only when existing and forecasted weather conditions will permit work to be performed in accordance with Subcontractor's recommendations.
- B. Erect frame and fabric in accordance with the procedures of the approved Subcontractor.

- C. Adequate prestress shall be applied to eliminate fabric wrinkles and excess cable sag. Membranes with extreme twist and/or shallow catenary curves may be more prone to wrinkles. The wrinkles should be minimized with adjustments and should not be a distraction when looking at the project as a whole.

3.3 FIELD QUALITY CONTROL

- A. Subcontractor's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Prepare test and inspection reports.

3.4 MEMBRANE PATCHING

- A. Any and all patching must be done by trained and authorized personnel.
- B. Minor repairs are defined as:
 - 1. A patch, no larger than 1% of the area of the fabric panel.
 - 2. Sewn or sealed reinforcement at corners or joints, sewing and sealing no greater than 12 inches in length.
- C. A maximum of one patch per membrane will be permissible.
- D. No more than two patches will be allowed for the entire project.
- E. Sewn or sealed reinforcement is allowed at all corners when necessary.

3.5 ADJUSTING

- A. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to one visit to Project during other-than-normal occupancy hours for this purpose.

3.6 CLOSEOUT ACTIVITIES

- A. Demonstration: Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust cable and fabric tension and to clean and maintain canopy fabric.

END OF SECTION