

SECTION 13121 - FRAME SUPPORTED MEMBRANE STRUCTURE

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of Contract, including General and Supplementary Conditions and other Division -1 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section specifies the furnishing and installation of a structural frame supported membrane fabric covered roof and wall structure of the type described herein.
- B. This system includes the installation of structural framing and fabric membrane at roof and at walls to the extent shown on the project drawings.

1.3 REFERENCES AND STANDARDS

- A. The following publications are for the standards listed below but referred to thereafter by basic letter designation only. They form a part of this specification to the extent referenced thereto:

1. American Institute of Steel Construction (AISC):

- a. M016-89 Manual of Steel Construction, Ninth Edition.
- b. S326-78 Design, Fabrication and Erection of Structural Steel Buildings.
- c. S329-85 Structural Joints Using ASTM A325 or A 490 Bolts.

2. American Iron and Steel Institute (AISI):

- a. SG 503-76 The Design of Fabrication of Cold-Formed Steel Structures.

3. American Society for Testing and Materials (ASTM):

- a. A36-89 Structural Steel
- b. A 123 A-89 Standard Specification for Zinc (Hot Dip Galvanized) Coatings on Iron and Steel Products.
- c. A 307-89 Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
- d. A325-89 High-Strength Bolts for Structural Steel Joints.

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1.3 REFERENCES AND STANDARDS (Cont'd)

- e. A 500 A-90 Standard Specification for Cold Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
- f. A 563 Rev A-89 Carbon and Alloy Steel Nuts.
- g. A 687-89 High-Strength Non-Headed Steel Bolts and Studs.

4. American Society of Civil Engineers (ASCE)

- a. 7-98 Minimum Design Loads for Building and Other Structures

5. American Welding Society (AWS):

- a. D1.1-2000 Structural Welding Code - Steel

6. National Fire Protection Association (NFPA)

- a. 701-89 Standard Methods of Fire Tests for Flame Resistant Textiles and Films.

1.4 GENERAL REQUIREMENTS

A. Scope:

1. This specification covers the design, manufacture, shipping and handling and erection of a relocatable, prefabricated tension membrane structure.
2. The structure membrane shall be tensioned over the framework. The structure shall be rectangular in shape. The side and gable walls of the structure shall be vertical. The interior of the structure below the main arch shall be clear and free of any structural members and shall provide unobstructed floor space.
3. The structure shall also include accessories and items required and necessary for the scope and intended use and as herein specified. These include:
 - a. Personnel access, industrial roll up and aircraft hangar doors.
 - b. Electrical systems including interior lighting.
 - c. Ventilation Systems.

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1.5 DESIGN AND DIMENSION

A. Exterior Dimension: The structure shall have the following minimum exterior dimensions:

1. Width: _____ +/- 3"
2. Length: _____ +/- 3"
3. Wall Ht.: _____ +/- 3"
4. Peak Ht.: _____ +/- 3"

B. Clear Interior Volume: Each interior bay of the structure shall provide as a minimum a clear unobstructed interior (usable cubic volume) of the following widths and heights with an overall clear interior length of _____:

1. _____ width at _____ above finished floor
2. _____ width at _____ above finished floor
3. _____ width at _____ above finished floor

C. Design Requirements- Structural Frame

1. Roof and Wall Surfaces: To provide for maximum compatibility with standard door, window, ventilation and other accessory and cladding systems, the structure shall be designed such that roof and gable side wall surfaces form flat planes.
2. Purlin Spacing: To provide for structural stability, to minimize unsupported areas of membrane fabric in the roof and to provide for installation of accessory items, the main structural trusses shall be laterally braced by tubular purlins. (See Part 1.8, C, Paragraph 7).
3. Wind and Frame Bracing: The structure shall be appropriately stabilized with main wind bracing cable or rod assemblies as well as any required secondary node restraint assemblies so as to efficiently transfer wind, snow and seismic induced stresses to the foundation/anchoring system. Cable diameters for main wind bracing shall be a minimum of 3/8" diameter for structures under 130' span. For structures between 130' and 200' span, cable diameters should be a minimum of 1/2" and for structures over 200' span cable diameters should be a minimum of 5/8". The end bays of the structure shall be designed to be "X"-braced early during installation to allow for permanent stability of the frame as early as practicable during the installation process. The structural frame shall be provided with engineered attachment clips or lugs for all main cable assemblies. These clips shall be a minimum 3/8" thick A36 steel and shall be designed to properly transfer wind bracing forces within the structural frame.

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1.5 DESIGN AND DIMENSION (Cont'd)

4. **Connecting Joints:** Connections between structural elements shall be properly designed with required safety factors so as to transfer the maximum compressive and tensile forces present in a given joint. For spans less than or equal to 90', a minimum of two 5/8" diameter A325 bolts or one 3/4" diameter A325 bolts shall be used at each main truss chord joint. For spans greater than 90' and less than or equal to 170', a minimum of two 3/4" diameter A325 bolts shall be used at each main truss chord joint. For spans greater than 170', a minimum of two 1" diameter A325 bolts shall be used at each main truss chord joint. Where sleeve joints are used, the material shall be appropriately sized and reinforced so as to avoid shear failure of the material. Primary axial steel connections shall also be made with bolts of at least 5/8" diameter grade A325. Secondary purlin shall be secured by no less than 1/2" diameter bolts.
5. **Mechanical Equipment Interface:** The main structural roof trusses shall allow for installation of electrical and mechanical equipment between the inner and outer surfaces of the truss framework. Likewise, the structure shall accept penetrations through the membrane for access doors and mechanical services with minimal modification.
6. **Alternative Cladding Materials:** The structure shall be designed such that alternative covering materials such as metal roof and/or wall cladding can be added with minimal modification, if required.
7. **Shipping:** The main structural trusses shall be two dimensional, planar trusses which nest tightly together in order to minimize shipping and storage volume.
8. **Ancillary Systems:** The structure shall be designed such that it can be readily retrofitted with insulation systems and other ancillary systems such as lighting, sprinklers, HVAC, etc., as required.

D. Design Requirements - PVC Coated Membrane Cladding System

1. **Continuous, Weather Tight Membrane:** The structure membrane shall form a continuous, uninterrupted weather tight shell over the framework. In order to provide for a good finished appearance and to insure weather tightness, the gable wall PVC cladding shall be manufactured so as to be connected in one piece to the adjacent side wall and roof cladding without the use of catenary cables.

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1.5 DESIGN AND DIMENSION (Cont'd)

2. Cladding Section Joints: Adjacent PVC cladding sections shall either lace together with a minimum 1/4" white polyester braided rope or be provided with a mechanical tensioning system so as to maintain PVC tension along the length of the building. Proper gaps shall be maintained between sections so as to allow sufficient distance to enable full tensioning of the material.
3. Overlap Seams: The membrane system shall be designed such that the PVC cladding panels can be supplied with optional overlap joints to allow adjacent panels to be field heat sealed together.
4. Base Tensioning System: The PVC cladding will be provided with a mechanical tensioning system that allows the PVC to be fully tensioned around the structure perimeter. The system will be designed such that the membrane can be tightly and neatly secured over the structural frame and such that the system has remaining range of adjustment.
5. Membrane Seal at Openings and Base: The structure supplier will provide all materials and methods necessary to fully tension and seal the membrane material around all door, ventilation and other openings as well as around the structure perimeter below the main tensioning system. This seal shall provide a neat and finished appearance and eliminate any loose PVC cladding that could otherwise be damaged by flapping or abrasion. When a PVC base skirt is required, this shall be supplied separately from the main PVC cladding and attached at the base perimeter so as to allow a reasonable seal against air and water intrusion.
6. Design Safety Factor: The PVC attachment and tensioning system shall be designed such that the completed system allows a factor of safety at design loads of at least three (3) times the theoretical design strength of the PVC material.
7. The structure membrane shall not be designed to function as a structural member such that, should any damage to or penetrations of the membrane occur, the integrity of the structural framework shall not be affected.

1.6 OPERATION AND USE

- A. The structure shall be designed to provide a minimum 15 year operational use period, which shall include, if necessary, one installation/disassembly cycle per year with appropriate inspection and maintenance.

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1.6 OPERATION AND USE (Cont'd)

- B. The structure shall be capable of being assembled, operated and dismantled in all ambient temperatures between -20°F and 120°F.
- C. The fabric material shall be designed to withstand a maximum temperature of 150°F when stored in packing containers.
- D. The structure shall be designed such that a crew of five persons working with a trained supervisor can unpack and assemble the basic structure at a rate of at least 2,000 square feet of surface area per day (35 square feet of structure surface area per person hour) on a prepared surface. Disassembly shall be accomplished at a rate of at least 2,500 square feet of surface area per day by a similar crew.
- E. The structure shall be capable of being erected upon various surfaces such as natural ground, asphalt or concrete and shall also be capable of accepting differential settlement up to 2-1/2% between truss positions.

1.7 ENGINEERING DESIGN CRITERIA

- A. The structure shall be designed in accordance with appropriate building code standards using methodology from ASCE 7-98. Primary and secondary framing shall comply with current issues of AISC, AISI, NEMA and ASTM specifications, as applicable. Structural members shall be designed using Allowable Stress Design (ASD) or Load Resistance Factored Design (LRFD) for the design loads given below. Appropriate safety factors to yield and ultimate shall be maintained. Wind load factors and coefficients used in design of structural members must be in accordance with ASCE 7-98 guidelines.
 - 1. Roof Loads: The structure shall be designed based upon a ground snow load of ___ pounds per square foot (psf) plus a 3 psf collateral load. At a minimum, the structure shall be capable of supporting a roof live load of 12 pounds per square foot and a collateral load of 3 pounds per square foot projected over the entire roof area or a portion of the roof area, and any probable arrangement of loading resulting in the highest stress in the members.
 - 2. Wind Loads: The structure shall be capable of withstanding 3 second gusts wind loads from any direction of ___ miles per hour. The structure shall be designed using an exposure category "C" for determining design wind pressure of the structure. The methodology is to be taken from ASCE 7-98.
 - 3. Rainfall: The structure shall be capable of withstanding the effects of rainfall up to 4 inches per hour for at least 2 hours.

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1.7 ENGINEERING DESIGN CRITERIA (Cont'd)

4. Deflection: The maximum allowable deflection of any point on the steel framework shall be no more than 1/180 of the clear span width of the structure when subjected to the design loads described herein.
5. Design Loads: The design shall be based as a minimum on the following load cases: (ASCE 7-98 (ASD) Listed)
 - a. D D = Dead Load + Collateral Load
 - b. D + S S = Symmetrical Snow or Live Load
 - c. D + (Ws or .7E) (Balanced or Unbalanced)
 - d. D + (Wp or .7E) Ws = Wind with internal suction
 - e. D + S + (Ws or .7E) Wp = Wind with internal pressure
 - f. D + S + (Wp or .7E) E = Earthquake

1.8 MATERIALS

All materials used in the structure shall be new, without defects and free of repairs. The quality of the materials used shall be such that the structure is in conformance with the performance requirements specified herein.

A. Cladding Membrane: The structure shall be clad with a PVC coated polyester fabric manufactured by an approved and reputable supplier with demonstrated long term performance . Laminated materials are not acceptable for use on the outer weather membrane. The PVC coated membrane fabric shall be waterproof and free from defects. All roofs, walls, end walls and connecting sections shall be weather tight. The material will be selected from the manufacturer's standard colors for the side walls and will be translucent white in the roof. The material must be UV stabilized and flame retardant, must carry a minimum five year manufacturer's warranty and must have a life expectancy of 15 to 20 years. The minimum fabric specification is as follows:

1. Coated Weight:	28 +/- 2 oz/sy	(Method 5401)
2. Base Fabric Weight:	6.9 oz/sy	
3. Finished Thickness:	30 mils	
4. Grab Tensile Strength, lbs:	690/620	(ASTM D751)
5. Tongue Tear:	180/180 lbs/in	(ASTM D2261)
6. Cold Crack Resistance:	-40°F	(ASTM D2136)
7. Flame Resistance:	2 sec flameout	(NFPA 701)
8. Flame Spread:	25 or less	(ASTM E84)

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1.8 MATERIALS (Cont'd)

Acceptable membrane suppliers include: Seaman, Ferrari, Protan and Mehler. Other PVC coated materials may be considered, however the membrane manufacturer must demonstrate a minimum of fifteen years successful field experience with provision of PVC coated polyester cladding in use on structures of the type contemplated in this specification.

B. Metal: All components of the structural framework shall be fabricated from steel. The primary material used in the structural arches shall be steel tubing which shall be to ASTM A500 specification with a minimum yield stress of 50,000 psi. Main truss chord members shall be no less than 2 3/8" outside diameter 11 gauge (0.120" thick) tubing for structures under 70' clear span, no less than 3" diameter 11 gauge for structures between 70' and 130' span, no less than 3 1/2" diameter for structures between 130' and 170' span and at least 4" minimum diameter for structures greater than 170' free span. No main span tubes or any compression member in the structural frame shall be less than 0.095" thickness. Flat bar and other shapes shall, at a minimum, be to A36 or equal.

1. Corrosion Protection: Welded steel work shall be hot dip galvanized to ASTM A123 after manufacture to provide corrosion protection. All other main steel components shall be galvanized to ASTM G-90 or equal.
2. Painting: Painting of steel components shall only be utilized if necessary for field repairs and shall not be employed as a factory finish. Should field repair be necessary, a zinc rich field coat shall be used.

C. Hardware:

1. Bolts: Bolts subject to extreme stress and wear shall be structural bolts of grade A325 or equal. All other structural fasteners shall be of Grade 2 or higher. All fasteners for interior use shall be zinc plated, hot dip galvanized or stainless steel. All bolts shall be installed and tightened per AISC Steel Manual Requirements. Those subject to removal or adjustment shall not be swaged, peened, staked or otherwise installed.
2. Anchor bolts: Anchor bolts shall conform to ASTM A36, A307 or A687.
3. Membrane Tensioning Hardware: The fabric membrane shall be tensioned with load rated hardware which is hot dip galvanized so as to prevent corrosion. Tensioning hardware shall allow for full and free rotation at the foundation connection so as to avoid fatigue failure of threaded assemblies.

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1.8 MATERIALS (Cont'd)

4. Cable Assemblies: Main wind bracing cable assemblies shall be manufactured to the required length and press swaged with stainless steel sleeves. The cables shall be properly sized with appropriate safety factors.
 5. Other Fasteners: Non-structural fasteners such as wood screws, tek screws, etc., shall be of standard commercial quality.
 6. Exterior Trim: Battens or washers used for final seal of the PVC membrane shall be either hot dip galvanized, stainless steel or aluminum to resist corrosion. Fasteners used for exterior trim work shall be stainless steel, zinc plated or hot dip galvanized.
 7. Purlin Spacing: Minimum purlin spacing shall be equal to or less than 7' for buildings with 170' free span or less and equal to or less than 12' for free spans greater than 170'.
- D. Welding: Welding shall be employed only when specified in the original design. Welding shall be performed in accordance with AWS D1.1. by welders qualified and tested to an acceptable standard. Welded joints shall be properly sized and placed. Welds shall have thorough penetration, good fusion and shall be free from scabs, blisters, abnormal pock marks, cracks, voids, scab inclusion, and other defects.
- E. Workmanship: The workmanship of all materials and components of the structure shall be of commercial standard quality commensurate with the functional requirements of the item. The basis for commercial quality standards shall be:
- Rubb Building Systems
P.O. Box 711, 1 Rubb Lane
Sanford, ME 04073 USA
- F. Manufacturer: The structure supplier shall be a reputable manufacturer; shall have a minimum of ten years direct experience in the design, manufacture and installation of structures of the type specified herein; shall operate according to a comprehensive quality system and shall provide documentary evidence as follows:
1. Provide three references with structures in use for at least five years which exceed one hundred (100) foot clear span and which enclose in excess of 10,000 square feet.
 2. Provide information of company experience and engineering and installation capability which meet the above experience requirements.

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1.8 MATERIALS (Cont'd)

3. Provide evidence of ISO 9000 certification or comparable quality certification.

G. Piece Marking and Identification: All individual parts or bundles and packages of identical parts are to be clearly marked for identification or otherwise identified by clear installation procedures. Bolts and fasteners shall be packaged according to type, size and length. Loose nuts and washers shall be packaged according to size and type. The shipping documents shall list showing the description, quantity and piece mark of the various parts, components and elements.

H. Material Delivery: The building system materials shall be delivered to the project site during normal working hours on weekdays. Installation contractor will provide adequate workmen and equipment to promptly unload, inspect and accept material delivery.

I. Handling: The Installation contractor shall be responsible for unloading, field storage, protection and transfer to the work area of all materials and equipment required to perform the work. At no time shall materials be dropped, thrown or dragged over the transport equipment or the ground. Damage to any piece under its own or superimposed weight shall be cause for repair or replacement. Materials shall be protected from standing water.

J. Short, Damaged or Excess Materials: Installation contractor shall inspect, count and verify quantities based on the shipping documents.

1.9 FOUNDATION DESIGN

A. The building manufacturer shall provide the purchaser with a copy of the foundation/anchoring requirements and, if applicable, the anchor bolt plan, truss and leg truss line location and reactions. The anchor bolt plan shall show the anchor bolt(s), material, number, size location, embedment, projection and spacing. Design of the foundation and/or anchoring systems for the building shall be in accordance with proper design principles with appropriate safety factors and shall be based on the maximum column/truss reactions as determined and provided by the building manufacturer.

1.10 ACCESSORY SYSTEMS

- A. Lighting - Description as required
- B. Insulating Liner - Description as required
- C. Doors - Description as required
- D. Ventilation - Description as required