

# LSAA

LIGHTWEIGHT STRUCTURES ASSOCIATION OF AUSTRALASIA INC.

## GUIDELINES FOR DESIGN, FABRICATION AND INSTALLATION OF TENSION MEMBRANE AND SHADE STRUCTURES

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This small document has been prepared to assist those parties who call for, those who submit designs, those who fabricate and those parties that install tension membrane and shade cloth structures in Australasia.

It provides guidelines for the industry to provide a high standard of product that meets the needs of end clients

This document is issued as a "DRAFT FOR COMMENT"

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## Foreword / Disclaimer

This Guideline has been developed by the Technical Sub-Committee of the Lightweight Structures Association of Australasia (LSAA). In preparing this document the committee has drawn from Australian design standards and other International Standards, Guides and Handbooks in both style and substance as deemed appropriate. The process adopted has been to produce a document that reflects a fair and reasonable consensus among all interested participants. One primary aim of the Technical Sub-Committee is to preserve public health, safety and welfare, however an independent assessment has not been undertaken and the LSAA does not warrant the accuracy, completeness, suitability or utility of any information, apparatus, product or process discussed herein. This guideline is not intended, nor should anyone interpret this guideline, to replace the sound judgment of a competent professional, having appropriate 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 the guideline.

LSAA has no authority to enforce compliance with this guideline and does not undertake to certify products for compliance or to render any professional services to any person or entity.

LSAA 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 guideline.

### Status

This guideline is under development and is issued as a draft for comment and subject to the conditions set out in the Disclaimer.

It is the intention of the LSAA to issue this guideline as a document for adoption by Industry in 2015.

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## 1 SCOPE

These Guidelines are concerned with "Tensioned Membrane Structures", also termed "Tensioned Fabric Structures".

The main applications are roof and shade structures made from flexible fabric materials which are fabricated to form pre-stressed surfaces capable of providing environmental protection from rain, hail, wind or sun.

The fabric materials may be solid or open in nature. Solid materials typically are woven yarns with continuous waterproof coatings. Open materials typically are knitted uncoated cloths known as "shadecloth".

The fabric for the roofs or panels are generally manufactured as rolls which are cut to pre-determined patterns and then joined by welding or sewing along the edges to form the final panels. The boundaries of the panels may end in edge cables, edge webbing, clamping to supporting cables, arches, beams or other structural supports.

The shape of the fabric surfaces is generally curved such that the shape is more suited to resisting environmental loads from wind, rain, hail, snow and maintenance loads.

The size and shape of the panels is such that generally they must be pre-tensioned so that all areas of the panels remain taut under fluctuations of loads.

The effects of these pre-tensioning loads is often many times the effects due to self-weight and generally result in large horizontal forces which must be resisted by the supports.

These Guidelines are concerned with both temporary and permanent tensioned membrane structures.

## 2 COMPETENT PERSONS

The design and realization of a tensioned membrane structure project requires the close collaboration of a number of competent persons or parties.

For small and medium sized projects, the process may be initiated by an end client through a fabricator who in turn engages a structural engineer and subsequently an installer. In this case the fabricator might also be responsible for costing preparation and might become the Tenderer.

For many smaller shadecloth structures, an installer may act as the project coordinator.

For large projects, other parties may include client/owners, architects, project managers, main contractors and other team members. In such projects the importance of early input from those with expertise cannot be overstated.

### 2.1 Structural Engineer

The structural design of the Tensioned Membrane Structure shall be carried out by a competent structural

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engineer who is experienced in understanding the nature of the applied loads including effects of wind, hail, snow, initial pre-stress loads and effects during erection.

The concept design development may involve input from end clients, fabricator and others.

The competent structural engineer shall be capable of:

- a. Developing a design which achieves the objectives of the end client or user
- b. estimating maximum fabric stresses under critical load cases including pre-stress
- c. estimating edge cable or clamping loads under pre-stress and environmental loads
- d. determining reactive loads onto attachment points, supports and foundations
- e. selecting a suitable fabric material for the intended purpose
- f. preparing suitable documentation and specifications of the design including the assumed design loads and compliance with existing Standards
- g. developing connection details which permit the efficient transfer of loads given that components such as cable lengths may need to be adjusted and approach angles of components may vary significantly during erection and/or under loads
- h. designing a suitable supporting structure, anchorages and foundations to resist the loads.

## 2.2 Fabricator

A competent fabricator shall be used to prepare the roof panels.

This preparation shall cover, but may not be limited to:

- a. ensuring that measurements and geometric details supplied are in fact correct before commencement of work
- b. correct handling of materials to avoid damage
- c. expertise with the type of fabric to be used
- d. the use of suitable fabrics for the intended purpose and life expectancy of the structure including familiarity with coatings, UV protection and correct selection of UV protected threads etc.
- e. use of welding and/or sewing to achieve seams that develop the full strength of the fabric unless specifically noted by the structural engineer
- f. the use of suitable components and details to the edges of the panels, corner attachment points and reinforced areas
- g. having procedures in place to ensure seaming is done so that "match marks" are maintained
- h. having procedures in place to record operators, material batches used, types of welds, stitching and other individual processes along the production path
- i. suitable training of operators as required including having available sample seams and similar details that can be used for comparative purposes
- j. the preparation of a maintenance manual for the end client

The fabricator may also be called upon to provide periodic inspection services and to be able to carry out minor maintenance as required.

## 2.3 Installer

A competent installer with prior experience of tension fabric structures shall be used to erect the fabric panels and attachment components.

Activities shall be carried out in a safe and methodical manner including, but not limited to:

- a. liaising with project managers, site supervisors, clients, main contractors, other trades on site, as appropriate, to ensure timely access to the site is possible
- b. the ability to develop a step by step assembly and erection procedure for the project

- c. the ability to prepare the site such as clearing of debris, adding of padding to resist abrasion whilst roof panels are moved across the site or lifted above existing objects, protection from sharp edges
- d. the ability to organize suitable cranes and other equipment and have this equipment operated by certified operators – and to have the ability to instruct these operators in any different procedures that may be required in handling large flexible and lightweight panels
- e. the use of safety harnesses, anchorage points for workers and generally provision of a safe working environment, often at height
- f. to have suitable numbers of hand tools, portable pulling devices, extra shackles, clamps etc. available so as to avoid delays in securing a roof panel against damage from wind during erection
- g. to be able to pre-stress the panels in a controlled manner to avoid local wrinkling and stresses
- h. to be continuously aware of weather conditions and forecasted weather conditions during the expected erection time period
- i. to have the ability and equipment available to secure any partially installed panel safely in the event of high winds, rain, electrical storm or other unplanned or planned delays
- j. to be aware of any Occupational Health and Safety Requirements and other requirements from bodies such as Work Cover
- k. to ensure workers have the appropriate tickets or qualifications to match the work to be performed.

## 2.4 Patterning

For all tensioned membrane structures including temporary or permanent and to be made from any fabric material, it is vital that an experienced person be engaged to determine the required cutting patterns.

Patterns are to be determined such that the panels can be installed or attached to the supporting structure with the required level of pre-stress and be taut and free from areas of wrinkles.

For unique doubly curved designs using coated fabrics, the patterns are normally determined by specialized 3D software packages where material testing has been used to determine the load – deflection (stress – strain) of the material to be used in the project.

For designs that are fabricated repeatedly, it is advised to verify the cutting patterns based on suitable prototypes. Some temporary shelters may use this approach.

It should be made clear which party will assume responsibility for the patterning.

## 3 ESTABLISHMENT OF BRIEF WITH CLIENT

### 3.1 Overall Performance Requirements

A structure shall be provided which meets the needs of the client. The basic needs of a client may be very broad in scope at the start of the design process.

The tenderer may be required to interpret the needs of the client when developing a conceptual design. The tenderer, being considered an expert in the field, must have the best interests of the client in mind and work together to arrive at clearly defined overall performance requirements.

A client may require an area to be covered with a waterproof roof in which case the design criteria would need to cater for water run-off and possibly for wind driven rain. The roof should also be

designed to avoid water ponding or be able to resist the accumulation of snow and hail.

A client may require an area to be protected from the sun in which case the design should demonstrate predicted shade patterns for the required seasons and time of day. If an open fabric is proposed then the effectiveness of its shading properties should be stated clearly.

### 3.2 Preparation of Tender

If the invitation is not accompanied by a clear concise brief from the client then the tenderer should supply an indication of the quality of his tender including information on the following, as appropriate:

- a. Fabric type, coating, tensile strength, and information on behaviour under fire and estimation of rate of ultra-violet degradation.
- b. Corrosion protection to fittings and cables.
- c. Assumptions with regard to ground conditions and ground anchors.
- d. Assumptions based on site survey or lack of site survey and other information.
  - e. Design wind speeds and any other loading on the structure.
- e. Site conditions required for erection methods chosen.
- f. Clear time scales required for ordering of material and development of detailed design and cutting patterns.

### 3.3 The Submitted Tender

The Tender should state:

- a. Which consultants are responsible for the design, fabrication and supervision.
- b. Specify appropriate terms of engagement.
- c. Alternative proposals and options should be clearly outlined and costed fairly.
- d. Any changes to the original tender brief should be communicated to all tenders for their re-pricing as required.
- e. Tenderers should agree to participate only on the basis of fair evaluation and disclosure by the client following tender closing date.
- f. Conditions and precautions relating to temporary use, storage, handling and reuse if necessary
- g. Relationships with other Designers, Consultants and Contractors on the site.
- h. Work to be done by others.
- i. Extent of Working Areas and staged construction.

## 4 COMPOSITION OF GROUP SUBMITTING TENDER

The team proposed to a Client for supply and erection of membrane structures should include access to the following expertise with areas of responsibility clearly agreed prior to submitting tender:

- a. A practicing structural engineer.
- b. A specialized designer experienced in producing cutting patterns and cable lengths and being able to detail complex connection details.
- c. An experienced fabricator aware of the importance of quality control in manufacturing membrane structures by sewing and welding.
- d. A contractor able to manage and co-ordinate the personnel and equipment required for erection.

- e. How the project is financed between progress payments.
- f. A mechanical/electrical services engineer where appropriate for air supported structures or where specific internal environmental conditions are critical to the performance of the structure.

## 5 MINIMUM DESIGN STANDARDS

### 5.1 Existing Standards

The designers should be aware of the following codes, authorities and ordinances:

- a. Building Code of Australia
- b. Loading Code (AS/NZS 1170)
- c. Steel Structures Code AS 4100
- d. Fabric testing standards (Local or overseas)
- e. Fire testing standards
- f. Shadecloth standards
- g. Standards for threads, webbings, cables, shackles etc.
- h. Workers Safety Regulations (Personal Protection Devices etc.)

### 5.2 Minimum Design Procedures

- a. The designer should specify the following minimum strength testing for the membrane material: strip tensile; tear; seam strength.
- b. The ground condition should be investigated and major compression and tension reactions tested for ultimate load and deflections as appropriate.
- c. Analyses consistent with the scale of structure and materials used should be carried out to determine maximum loads and stresses.
- d. For structures over 600 square metres, a nonlinear, large deflection computer analysis is recommended.
- e. The use of wind tunnel testing may be considered for significantly sized or important structures sheltering large crowds such as with stadiums.
- f. For structures of knitted shadecloth, allowance shall be made for wind drag effects during large deformations. In the absence of more detailed analysis, all drag loads shall be assumed to be resisted by the edge cables/webbings on the windward sides.
- g. The design shall avoid excessive deflections of the structure where contact with sharp objects might result.
- h. Factors of safety against collapse should be stated if possible.
- i. The design life of the structure shall be estimated and stated.
- j. For structures whose main purpose is protection from the sun, appropriate shading patterns are to be provided for 10am, 12noon, 2pm and 4pm for the end of each month September through to April if requested.

## 6 MINIMUM FABRICATION STANDARDS

- a. The fabricator shall be satisfied that the layout dimensions for on-site attachment points and footings, including holding down bolts are accurately known before proceeding.
- b. The cutting patterns for new designs should be verified by a physical model constructed to a suitable scale or by 3D computer model.



- c. Membrane seaming joints should develop the full strength of the fabric being joined unless otherwise specified by the structural engineer. New materials/methods to be subject to proof testing. Sample seams shall be available for operators to compare against.
- d. Load entry and exit points to the membrane should be appropriately reinforced.
- e. The fabricator shall pay attention to folding and handling and jointing of the membrane to ensure minimum damage and staining of the membrane.
- f. All welders shall be experienced in operation of high frequency welding, and the receipt, inspection, production and dispatch shall be supervised by a person experienced in this field.
- g. Tolerances shall be stated and worked to.
- h. Continual visual and physical quality control procedures, properly recorded, shall be undertaken.
- i. Membrane materials shall be visually inspected for defects on the roll prior to cutting and seaming.
- j. Fabricated elements shall be clearly marked for identification during transport and erection at site.
- k. Clear instructions shall be given in respect of the transport and storage of fabricated materials.

## 7 MINIMUM ERECTION STANDARDS

- a. The safety of the public and site personnel shall be paramount at all times.
- b. Site assembly and erection shall be supervised by a suitably qualified person experienced in the scale of work and technology involved.
- c. Both the design and erection procedures must be developed with prevailing site weather conditions in mind. Limiting wind velocity at time of erection should be stated in the design.
- d. Qualified riggers shall be used where appropriate and Government Department OHS Regulations adhered to.
- e. The Contractor shall have proof of current insurance for the project and the workmen involved.
- f. The Contractor shall obtain approval of a qualified consulting engineer for footings and anchors prior to commencement of erection.
- g. The Contractor shall not leave the structure in an unstable state at any time and shall plan the erection sequence in stages to ensure safety during and at the completion of each stage paying due attention to weather forecasts.
- h. Removal or disassembly of membrane structures shall be properly planned and carried out to standards equal to those required for initial erection.
- i. Erection procedures for all but the smallest structures should be documented in words or sketch form and backed up by calculation as required before site assembly is commenced.

## 8 MINIMUM MAINTENANCE STANDARDS

- a. Initial inspections shall be carried out by the Contractor at 1 month and 6 months for the purpose of re-tensioning and examining the structure for signs of wear / vandalism.
- b. An operating manual shall be provided within one month of practical completion showing the main structure and design forces assumed, and maintenance / inspection procedures.
- c. An erection / demounting sequence shall be stated in the manual together with temporary bracing for renewal of the membrane in the future if required.