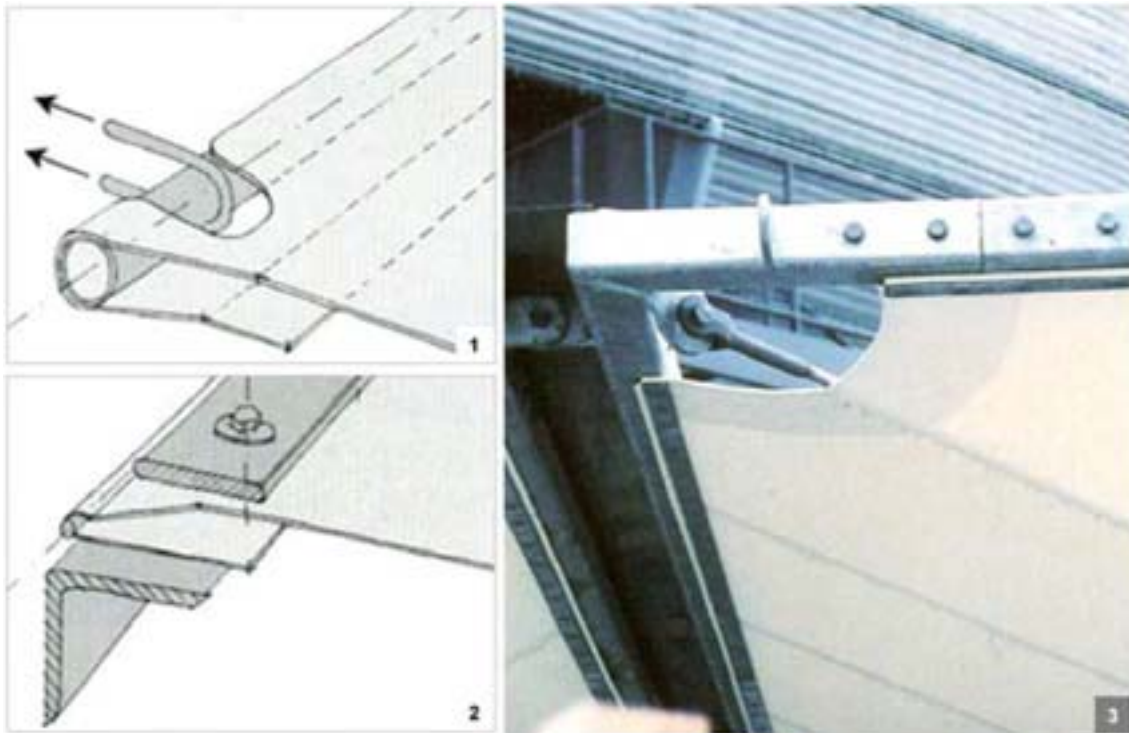


## RIGID EDGES FOR STRUCTURAL MEMBRANES

Although structural membranes should be connected according to their behaviour through flexible edges, there is often the need to connect them to rigid supports such as beams, arches or buildings. A research has been carried out on feasible available solutions.

Rigid edges held continuously the fabric by a supporting structure having much greater lateral stiffness compared with that of the fabric. They are collected by bending resistant structural elements that need to be trussed, thin or lightweight to avoid struggles against the lightness of the membrane. Form finding and surface control are easier. Foundations may also be simpler avoiding anchors.



**1** Tube in a pocket. Forces travel perpendicularly into the tube. Movements along the tube have to be prevented and the angle for the pocket has to be chosen to be small enough to limit peeling forces in the seam.

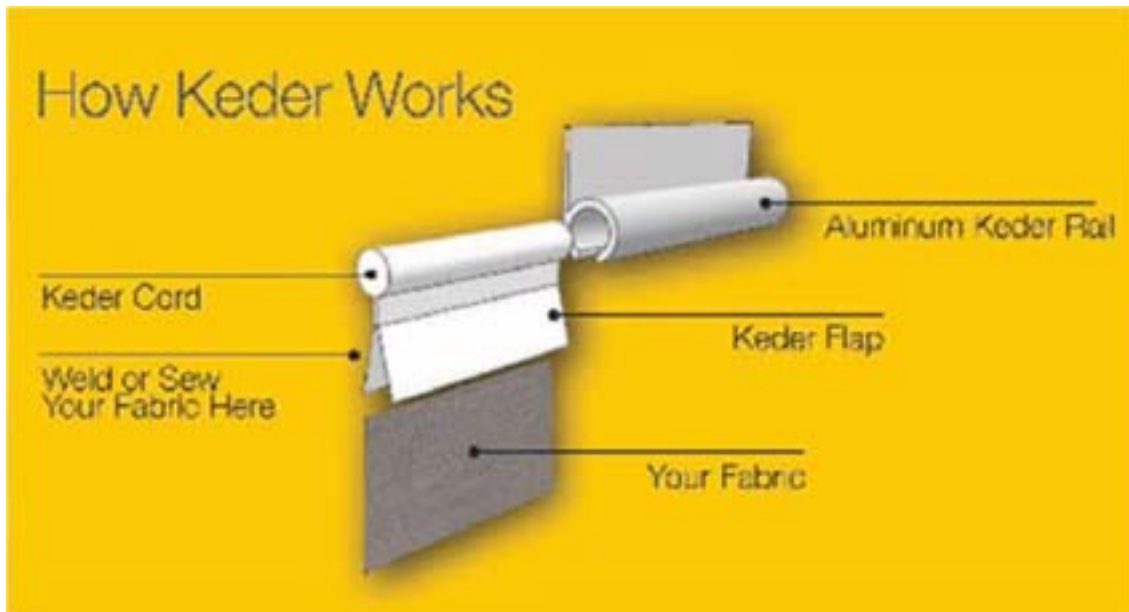
**2** Clamped edge similar to clamped seams but there is only one layer of cloth.

**3** The fabric is clamped on a rigid frame. Tensioning has to be introduced elsewhere.

### Keders

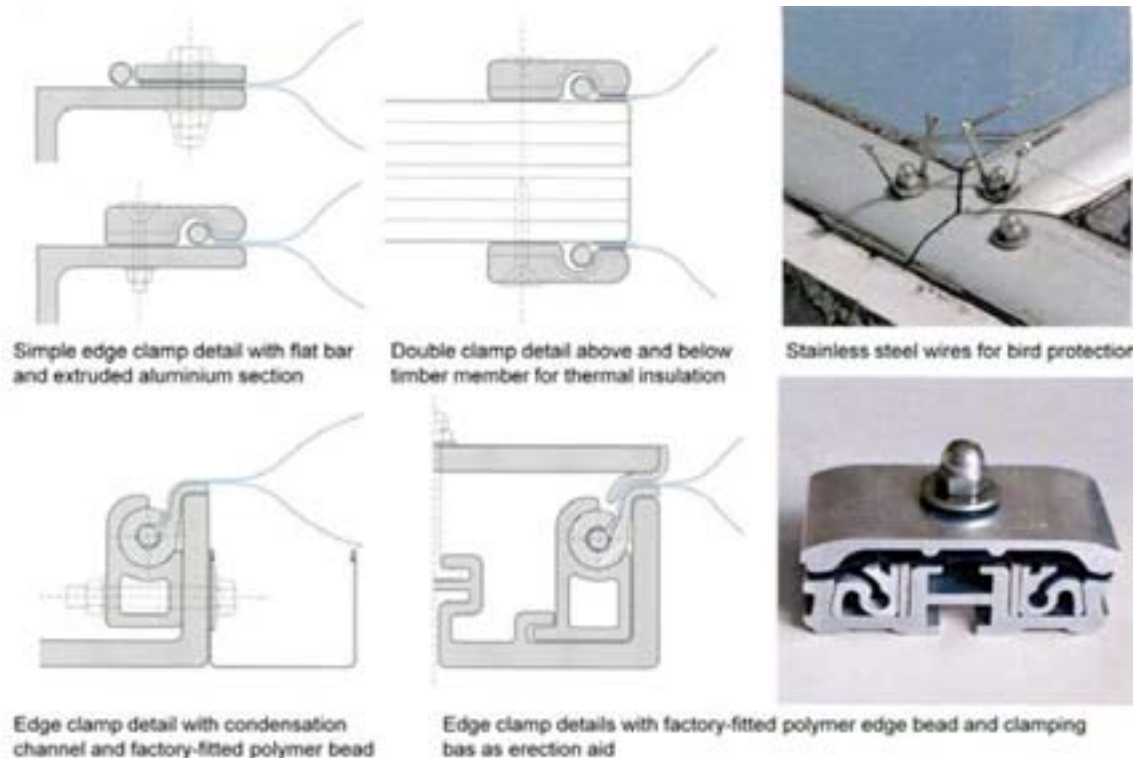
Continuous rigid joints between the edges of the membrane and the support structure can be provided by keder rails to form structural, interlocking connections. Keders can be made from polypropylene, PVC monofilaments or polyurethane (PUR). In order to ensure that the keder does not deform under load to such an extent that it slips out of its rail, it should exhibit a shore hardness of at least SH 50. Steel ropes or round aluminium sections can be used for the keders in tensile structures. Ropes made from polymers are generally unsuitable because of their relatively flexible construction. (Knippers et al. 2011).

As with lightweight types of membrane, keders can also be welded into strips along the edges of a foil, since recent ETFE applications have led to their use becoming more widespread.



Keder consists of two parts: a core and fabric. The core is made from extruded PVC, or another elastic material, to allow flexibility. The core is then wrapped in Keder fabric, which has exposed fibers on the outside to allow the Keder to easily slide into an extrusion with a luff groove – keder track. It has coating on the inside, to ensure proper adhesion during welding. (<https://www.kedersolutions.com/what-is-keder/>)

With pneumatic cushions, foil layers can be clamped together in a single keder rail or separately, in order to avoid thermal bridges and for ease of maintenance and replacement. The sections are generally extruded anodised aluminium products and clamping details can include strips made from elastomeric materials laid between the foil and the clamping sections in order to protect the foil against all mechanical, chemical and thermal actions. Such elastomers can be integrated directly into clamping elements in the form of factory-fitted polymer edge beads (J.Knippers et al. 2011).



Requirements of the clamping along the edges:

- accommodating tensile stresses
- transferring loads to the supporting structure
- self-supporting requirements
- clamping several separate layers also when made from different materials
- accommodating thermal expansion
- providing thermal insulation/break along the edge
- functioning as a gutter for rainwater
- functioning as a gutter for condensation
- fixing air supply components and lighting units
- accessibility for maintenance work
- bird control
- support during erection

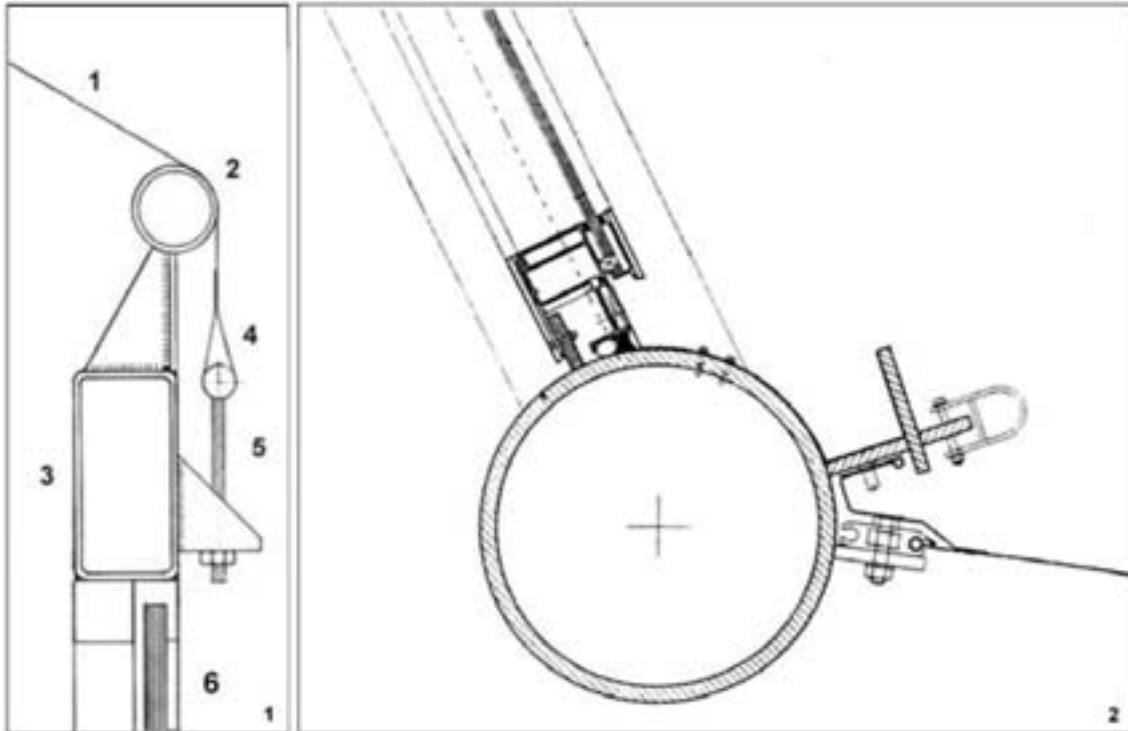


A bending-resistant structural element collects edges and stresses. Stiff edges are thick and contradict the thinness of the membrane. They would need to be trussed, thin or lightweight in order to avoid conflicts in form.

**1** The membrane is clamped directly to the CHS.

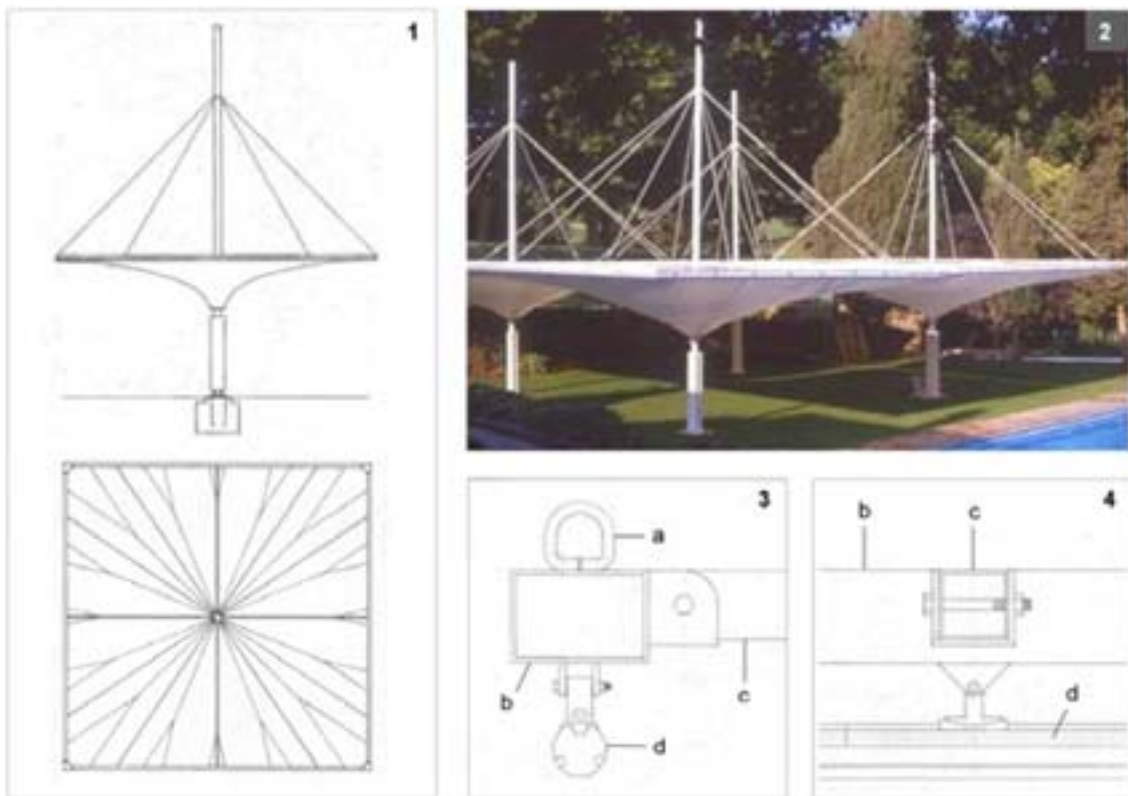
**2** Rigid edge with direct clamping of keder to fix firmly the membrane to the rear concrete retaining wall. (Unold, Architect with sbp and Sarnafil, 1998: Urban Rail-Link Station, Stuttgart. DETAIL 4/1994)

**3** Textile halls frequently resort to extruded aluminium RHS with rails to accommodate keders.



**1** The membrane is connected to the rigid vertical enclosure by a CHS. The gap is closed by a continuous flat section. Observe the tensioning device: 1 Membrane. 2 CHS. 3 RHS. 4 Pocket. 5 Tensioning screw. 6 Glazed screen.

**2** The membrane is fixed to a rail bolted to the welded plate. Note the seal skirt for water-tightness.



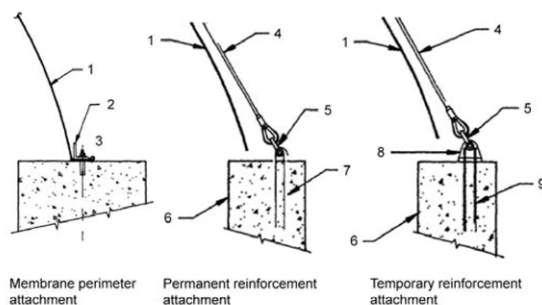
Llorens & Soldevila, Architects, 1987: "Golf Club Canopies", Sant Cugat del Vallès.

**1, 2** For the 1987 Spanish Golf Championship, part of the garden of the Sant Cugat Golf Club, next to the club's pool, was covered with four 9 x 9 m square removable modules.

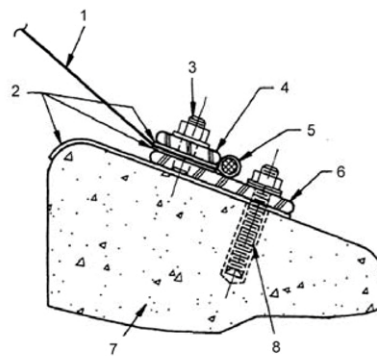
They have the form a funnel in order to acquire the double curvature necessary to resist the wind and drain. The low points include the pre-tensioning devices and drainage.

**3, 4** The perimeter of the funnels is a frame consisting of 4 120 x 80 mm RHS hung with ties from the central masts, so that it is left completely open and continuous without struts or joinery that would delimit the interior space. **a)** Welded ring for tie. **b)** Frame RHS 120 x 80 mm. **c)** Bracing SHS 60 x 60 mm. **d)** Keder rail.

The views towards the pool and the garden are not interrupted. The hanging ties subdivide the span to reduce the thickness of the RHS steel sections so that they do not contrast disproportionately with the 1 mm thin membrane.



Air-supported structures (ASCE & Birdair)



Membrane perimeter attachment for air-supported structures (ASCE & Birdair)

**1** Membrane

**2** Steel angle

**3** Anchor bolt for permanent installations or removable expansion anchor for temporary installations

**4** Reinforcement cable with thimble and swaged sleeve end

**5** Shackle

**6** Foundation

**7** Bent strap or rod embedded in concrete

**8** Steel lug plate

**1** Membrane

**2** Steel angle

**3** Anchor bolt for permanent installations or removable expansion anchor for temporary installations

**4** Reinforcement cable with thimble and swaged sleeve end

**5** Shackle

**6** Foundation

**7** Bent strap or rod embedded in concrete

**8** Steel lug plate