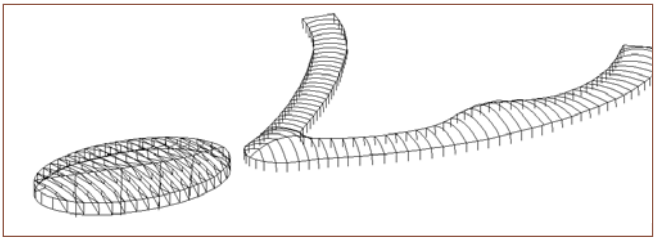


Meandering design of Arcade roofing. 94 different cushions, 112 in total

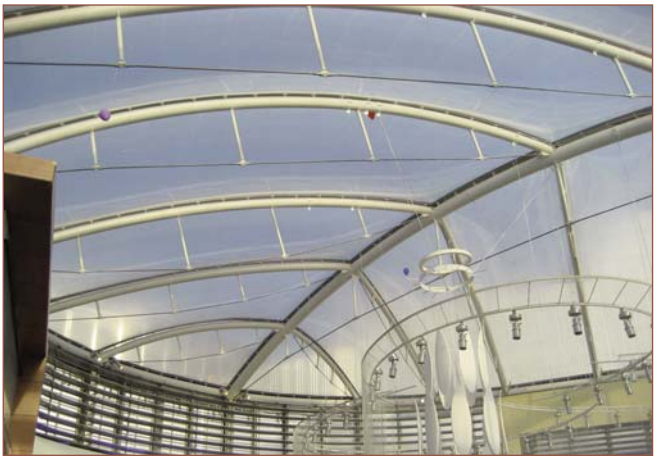
ETFE-CUSHION ROOF
ISLAZUL SHOPPING CENTRE MADRID

View at the malls (IASO, S.A.)

For the client Grupo LAR Agente Urbanizador,S.L the architect L35 Arquitectos designed a shopping mall with an interconnecting roofing over the arcade. The objective of the roofing is to give the visitors the feeling of being in an open air shopping centre in all zones of shops, bars and restaurants. To reach this goal a light and transparent cover is proposed with great translucency without disturbing the view towards the Spanish sky. The cover has a free form design, meandering through the mall. At the same time the applied material should have a high longevity, complete watertight, resistance to severe climatologically circumstances and very good long term preservation.
Therefore an ETFE cushion roof was proposed with two layers of 250µm ETFE-foil. The cushions are modular, following the main tubular steel structure, placed parallel or radial according the plan view surface to be covered.

STEEL STRUCTURE

The "lattice" pretensioned arcades, supported on steel tube pillars, are formed by tubular round steel tubes with a slightly curved shape in the upper part, with in the lower part solid tension rods. In between the tension rods and the upper arch, vertical round steel tubes absorb the compression forces in this structural "lattice" element. The arcades are only connected along the side girder without any connection along the arches. This gives an extreme lightweight sensation. As the cushions in between the suspended arches stabilize the arches horizontally, > p.16



The "lattice" pretensioned arcades

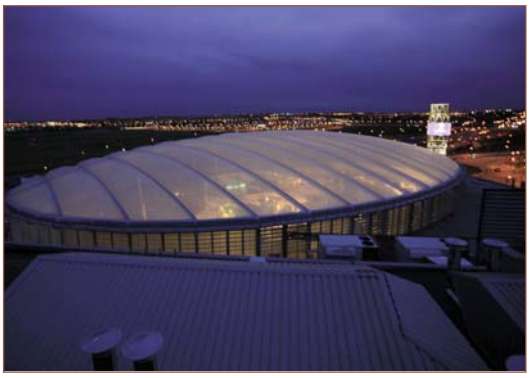
there is no need for interconnecting girders. In case of a cushion failure, the arches will deform strongly, but stay within the elastic range and therefore creating a safe and stable structural system. In the preliminary design the tension rods originally were designed as cables. To obtain more stiffness, it was chosen to use tension rods. This also implicated that there should be a very high accuracy of the steel production and a special pre-bending procedure has been developed to ensure that the steel structure has the required shape and pretension after installation.

DETAILING

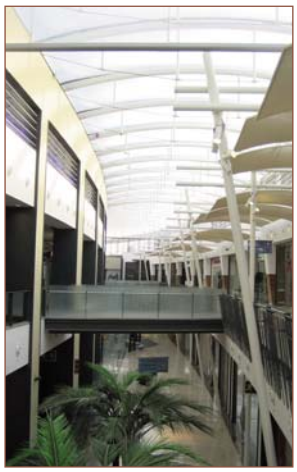
The cushions are fixed on aluminium profiles which are connected through bolt connections to the main steel structure with a condensation gutter in between. Experience of the glass facades was used to develop a special connection technique to ensure water tightness at the connection of the successive profiles. Each cushion consists of two layers of ETFE foil.
The upper layer is being printed on the inside part of the cushion with little silver coloured dots to improve the G-value. As the G-value depends on the location and sun intensity, a mock-up was build with 4 real-size cushions to measure the G-value of 4 different printing patterns. This also gave the client and the architect the possibility to evaluate the transparency of the different resulting cushions. Based on this research and G-values measurements a specific printing pattern is chosen.
To control the inner climate below the roof, there are horizontal lamellas situated with a height of approximately 2 m along the full perimeter of the roof. This creates a large ventilation capacity and therewith preventing the heating up of the air below the roof. To prevent an additional uplift on the roof at high wind speed, the lamellas can be closed. Also when the weather is not so well the lamellas will be closed.

The printing of the foil is only at the upper foil. The lower side is completely transparent. Both layers have a thickness of 250µm.
The cushions have a controlled inside air pressure of 300 Pa, inflated by dry air ventilators. The air reaches the cushions through a galvanised spiral steel pipe distribution system. The roof is divided into sections. Each section has its own blower unit and emergency unit.
Wind speed and snow are measured and with that input the internal pressure is altered consequently.

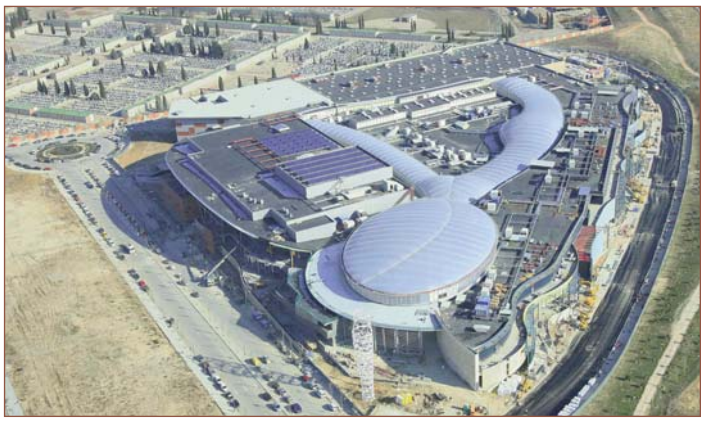
Inside view by night (IASO, S.A.)



Malls by night (IASO,S.A.)



Interior views, with additional membrane shading (IASO, S.A.)



Bird eye view of the finished roof (grupo LAR)

FORMFINDING AND STATICAL ANALYSIS OF CUSHIONS

For the analysis of the steel structure a governing load is determined which the air cushions apply onto the steel structure. As there is hardly any repetition in the cushion shapes, a procedure had to be determined to obtain a uniform looking cushion roof with no excessive cushion shapes.
To determine the range of stresses that should not be exceeded, several long term tests were carried out on ETFE foil at high temperatures.
From this tests a stress level was derived that should not be exceeded during the formfinding procedure.
The resulting cushion shape is submitted to wind load for several critical cushions to determine the governing stresses in the ETFE foil.
It is assumed that under wind load the cushion acts as a closed body and an interaction takes place between the inner pressure of the cushion and the outer load. As the height of the arches is increasing with the span of the arch and sometimes even is enlarged, cushions can have strong curvature. Especially the lower foil has to follow strange curves. At the ends of the cushion it is often anti-clastic curved while in the middle part it is synclastic curved.
This results in patterns that start to be convex, gradually go to be concave and then again go to be convex. Therefore the distortion that is asked from the material must be spread out evenly.

Client:	Grupo LAR Agente Urbanizador,S.L.
Architect:	L35 arquitectos
General engineering and detailing:	I.A.S.O, S.A. (Spain)
Steel structure engineering:	Ramón Sastre (Architect) Eva Porcel (Architect) / IASO, S.A.
ETFE-cushion engineering:	Tentech,bv. (The Netherlands) I.A.S.O, S.A. (Spain)
Project management:	Bovis Lend Lease
Membrane manufacturing:	I.A.S.O, S.A. (Spain)
Installation:	I.A.S.O, S.A. (Spain)
ETFE:	10000m^2 (plan view 250µmETFE)
Soltis 92 (Ferrari):	1250m^2
Batyline HM Tweed (Ferrari):	750m^2
Inauguration:	April 2008

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