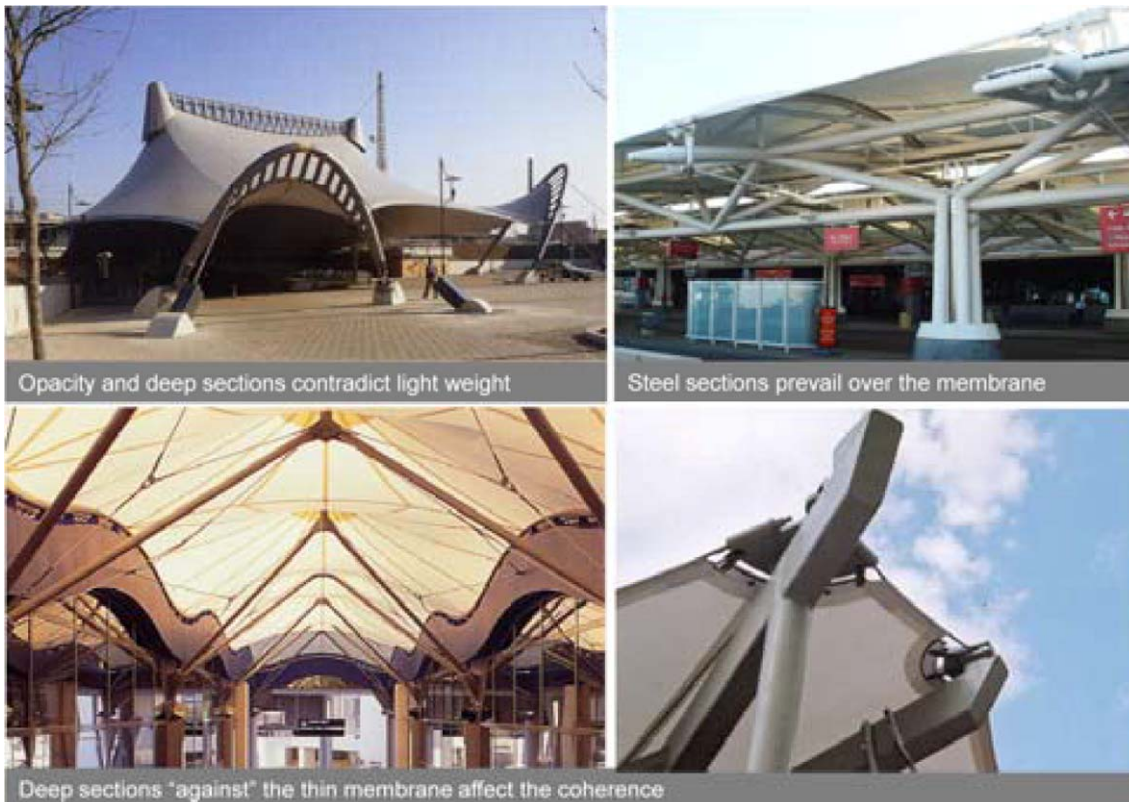


VISUAL EXPRESSION OF STRUCTURAL MEMBRANES

In tensioned membrane buildings the membrane is the protagonist of the architectonic space. Understanding this is vital to securing the building aesthetic qualities. Consequently great care has to be taken during the design phase to think how all elements can be integrated within a membrane enclosure, including structure, building services, joinery, furniture and finishes. Joints and connections are left exposed. Together with the membrane and other structural components, they fashion the appearance of the design as a whole. Care should be taken regarding the coherence, simplicity, lightness, balance, proportion, smoothness and style, because *visual expression factors are not only visual*. They are also indicators of structural, geometric and functional suitability.



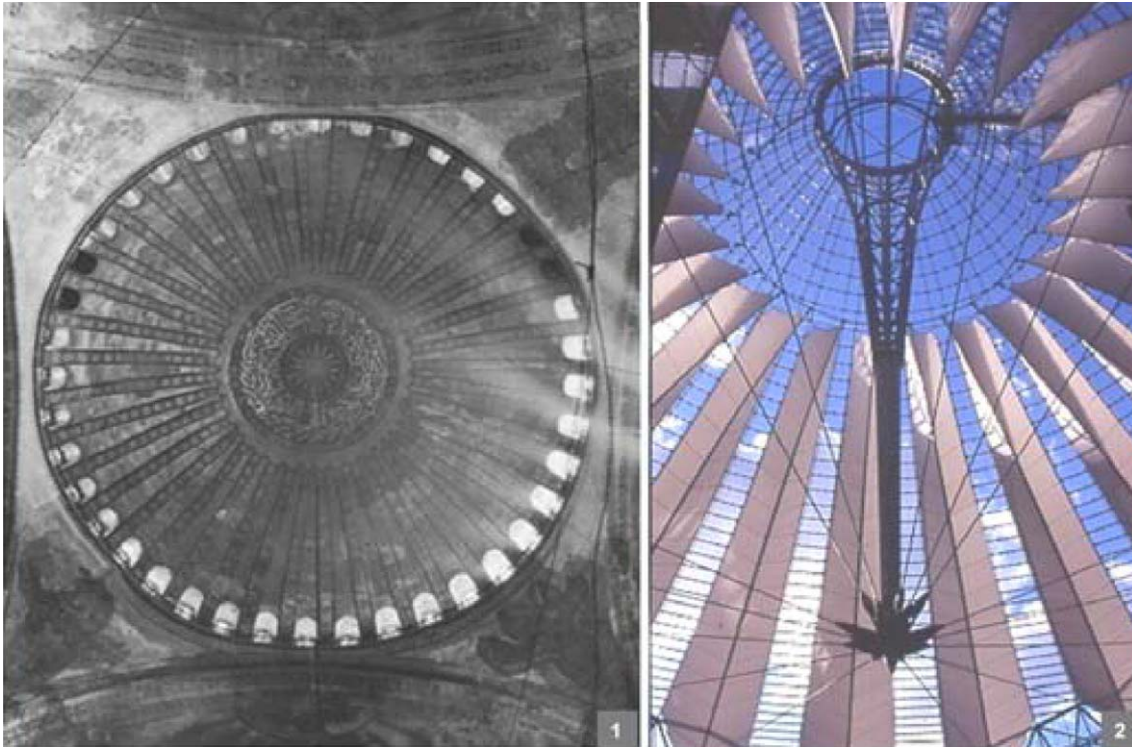
Coherence and homogeneity.

Membrane structures are lightweight and translucent. Surfaces follow load paths. They express neither thickness nor mass. They use a minimum amount of material. Preserving these characteristics in the details prevents strange and contradictory structures. Care should be taken with rigid enclosures connected to the membrane. Contradictions caused by differences of depth may arise. In the bottom left heavy reinforced concrete beams follow the curvature of the membrane. Nevertheless, their depth does not fit its lightness and the whole is perceived unbalanced and disproportionate.

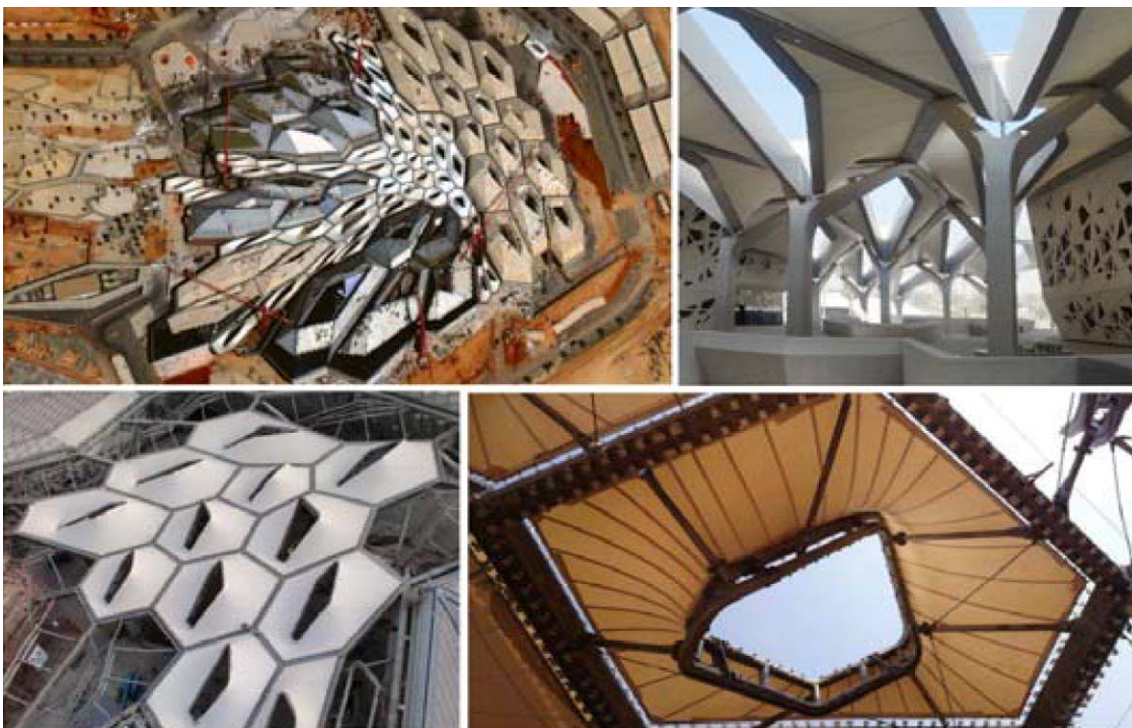
Lightness and simplicity

"Lightness does not only signify lightweight or low weight. It is an architectural approach" (Jürgen W.Hennicke). Lightness also (and mainly) depends on light and proportions, as many outstanding examples reveal. Fabric structures in architecture are not spared from this principle. The design of the details contributes significantly to the general appearance. If

undersized, they can result in a rupture. If oversized they detract from the visual slenderness of the membrane.

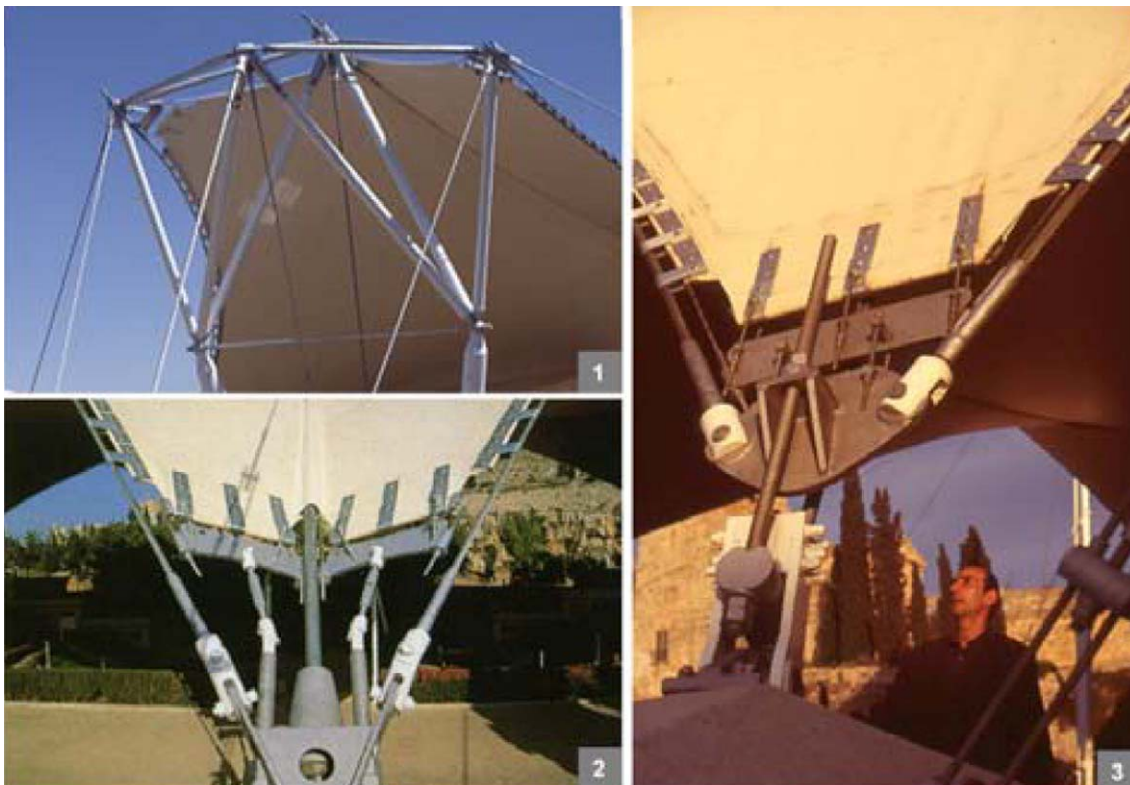


1 The dome of Santa Sophia is made of stone, but it looks light because a row of windows puts it suspended in the air. **2** Instead, the unique flying mast of the Sony Centre looks very heavy because of the contrast with light membranes and transparent glass.



To provide shade and ventilation, a dramatic sculptural mixture of fabric and steel was designed by Zaha Hadid Architects and Arup with Tensys and Labor Blum for the KAPSARC, King Abdullah Petroleum Research Centre in Riyadh Saudi Arabia. Hexagonally shaped cells of

very varying dimensions are arranged in a continuous, organic, crystalline looking layout that spans the major central courtyard area and the streets that are formed between the major blocks of the building complex. For each cell, a deep perimeter beam provides upper and lower boundaries to fix double-skin semi-translucent membranes. The double skin forms an insulation cavity of 0.5 m to 1 m and obscures the seamlines. It also hides the supporting steelwork of the central ventilation aperture in a manner that the daringly shaped membranes appear to magically suspend the central openings. Other special challenges were the minimum 140 kN/m breaking strength of the fabric and the varied compensations needed. In summary, it is an astonishing, oversized structure, showing once again that structural membranes, if not designed as such, require an imposing steel structure, as happened at the Beijing Olympic Stadium.



For the Camp de Mart Auditorium different solutions were adopted for the corners: **1** In the high points, complexity and concentration of stress were reduced by tripling the connections. **2, 3**: Nonetheless, in the low points, in spite of the fact that the dimensions of the corners are proportionate to the surface of the roof, they look oversized and complex because the proximity to the ground brings them near the spectator, changing the scale.

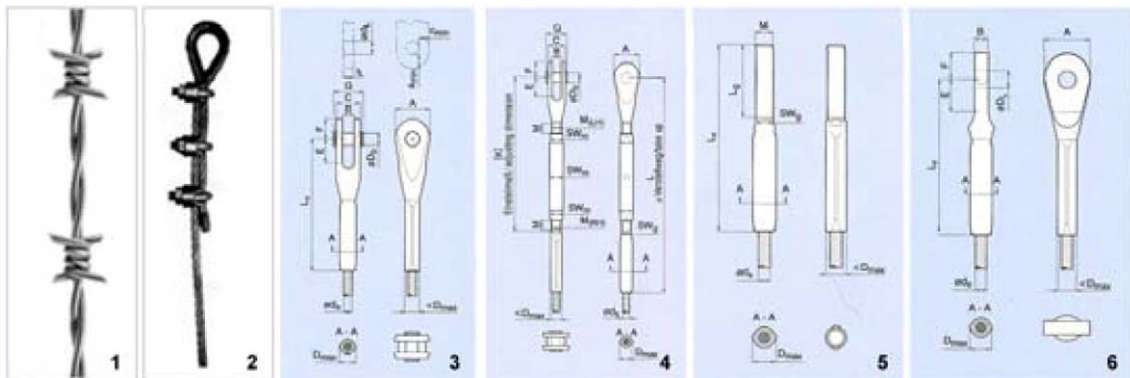
Additionally, the visual aspect is also related to the structural behaviour. Stiff components and moment-resisting connexions increase size and weight. These elements could be balanced by being simplified, split, subdivided, separated or removed. Flexibility and hinges also help.

Balance and proportion

Either consciously or not, we compare the whole with each individual part. Contradictions arise when complex devices and different types of fittings interfere with a simple scheme, instead of resolving problems by using the minimum number of elements possible and preserving the consistency of the proportions between the individual components.



1 Unbalanced situation, three heavy turnbuckles for so little \varnothing 12 mm cable closed with only two clips. 2 Excess of high-tech complexity. 3 Too much everything with different criteria. 4 Different types of fittings look clumsy. In addition, the shackle had to have been long enough to make room for the corner. The cable end is missing the thimble that would not fit in the turnbuckle.



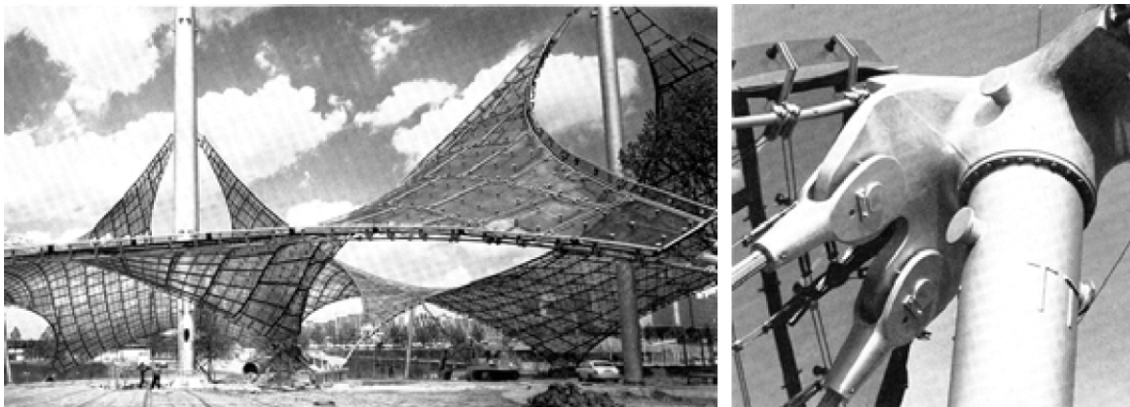
Fittings can also be aggressive or smooth. 1 Aggressiveness is obvious and desired. 2 Cable ends with clips are not smooth. They may cause injuries or damage. 3, 4, 5, 6: Smooth cable ends by Pfeifer: open swaged, turnbuckle with open socket, swaged with thread and closed swaged respectively. 7, 8 The rectangular plate and the cable do not fit together. An adapter is needed. The result looks clumsy.

Smoothness

Cutting edges and sharp points lead to stress concentration, damage and aggressiveness. Edges must be rounded off, bevelled and chamfered, and bolt ends softened. This applies not only to parts that are designed to be in contact with the membrane, but also to any metal parts that could come into contact with the membrane during erection.



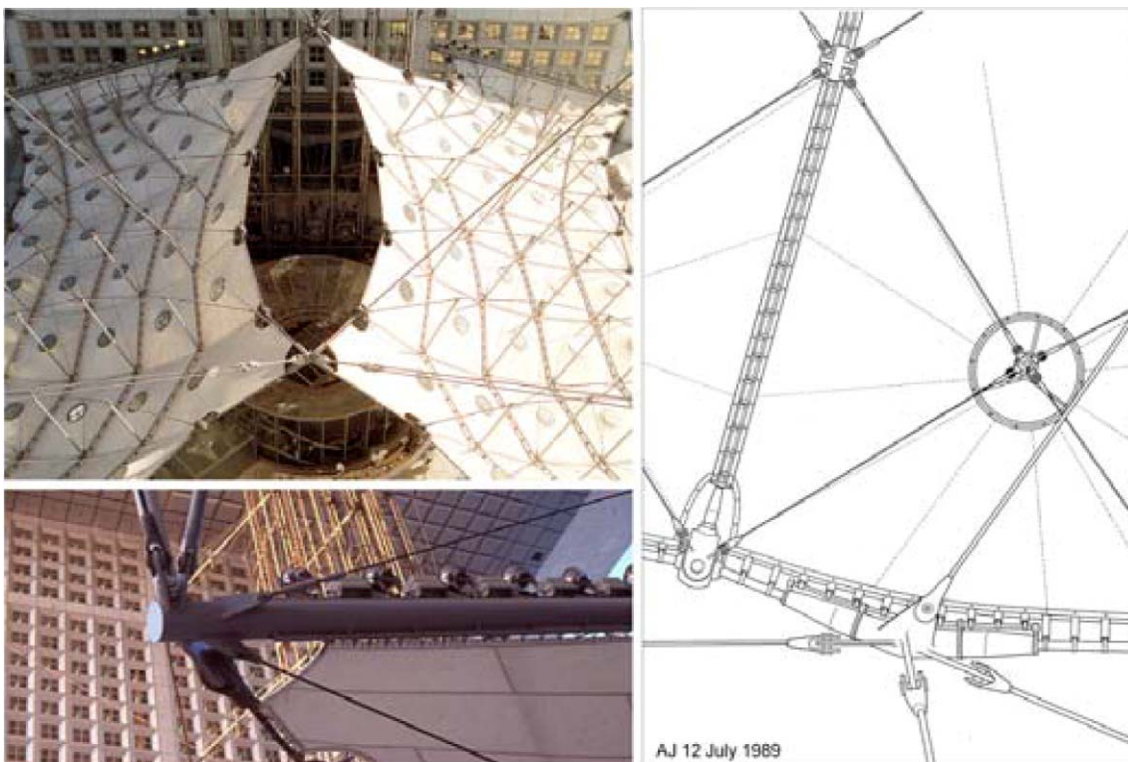
SATMB, 1990: Charter Terminal, Lyon Satolas. (80x30x9,5 m). Heavy loads and long distances require complex devices and strong reinforcements that may end up contradicting the lightness of the roof and the general concept. They should be simplified and placed far from the viewer to benefit from the distance.



Munich Olympia park, 1972. Left: Roof enclosure over the pedestrian walk between the stadium and sports arena. Right: Cast top of the mast. “Even if geometrically and structurally sufficient, visually reasonably well-balanced and remarkably accomplished, they seem blunted in feeling and perception” (T.Dalland, 1992).

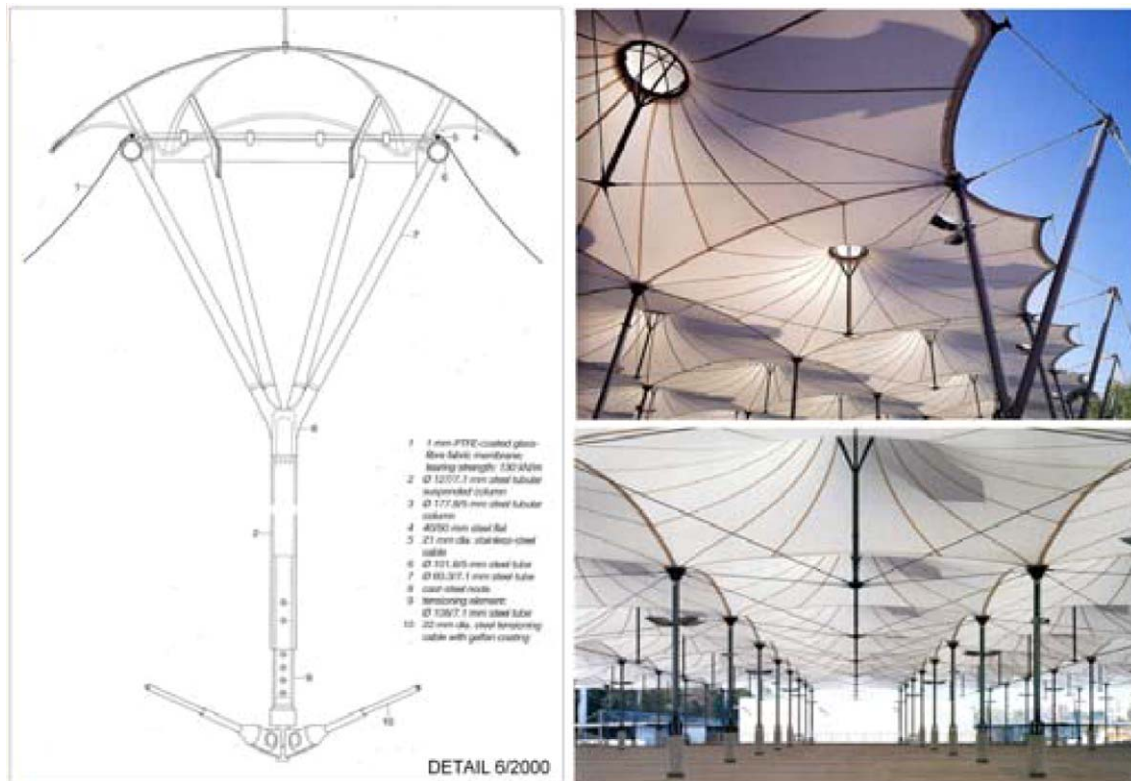


Details do not express technology alone. They form an ensemble that create a style. Their forms may connote sobriety, elegance, classicism, rationalism, decorativism, high-tech exhibitionism, or disturbing deconstructivism.



The cloud of la Grande Arche in Paris, for example, connotes high-tech sculptural exhibitionism due to the proliferation of cables and fittings. Light materials, a large span and the translucency of the fabric roof are an inspired way of representing the lightness and spontaneity of a cloud. Nevertheless, despite the fact that the design is well-articulated and accurate, the fragmentation of the surface, the size of the

details and the sharpness of the shapes lead to an excessive overall complexity. The lightness of the materials, openness of the site and clearness of the geometry are spoiled. The canopy looks over-structured, stiff and heavy. Instead of sheltering a volume that introduces a human scale, the proliferation of cables and fittings become a high-tech sculptural exhibition of tendons and muscles. Complex devices interfere with a simple scheme instead of solving problems using a minimum number of elements.



The building's visual factors are not merely visual. They are also indicators of structural and geometric harmony.

The lorry park of the Munich Office for Waste Management looked and was light. In addition to benefiting from the translucency of its membrane, it is also improved by the economy of its structural components and fittings. The design exploited the capabilities of the membrane.

There was a balance between the size of the modules and the resistance of the fabric. The spans were chosen wide enough to let lorries pass through but without being too wide, in order to avoid or reduce the presence of secondary elements, such as cable nets or beams.

Detailing was simple, coherent and homogeneous. There were few different types of fittings and sharpness was avoided by the utilization of rounded or tapered cast cable ends and plates. This emphasis on simplification also affected the system used for drainage, which was channeled through the columns instead of being exposed and adding vertical components. Hinges at the bases of the columns prevented the transmission of bending, which reduced the structure's complexity.

The whole design became clear and light—an expression of structural and geometric harmony. The details were not only derived from the general concept but end up defining the result.