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Developments in Structural Form to Minimise Environmental Impact

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Summary

Long span 'lightweight' structural forms employ low embodied energy because of direct force transfer. They can also create naturally light environments without the requirement for large amounts of non renewable energy for heating and cooling. They can form sustainable and delightful architectural spaces complementary to the existing rural or urban context with a minimum of environmental burden.

Abstract

In the light of the Rio Janeiro 1992 summit, architectural structures, even more then before, still need to be beautiful, comfortable and functional if they are to be sustainable and yet their construction depletes natural resources by embodying energy and their operation can consume non-renewable energy. Both have bi-products which increase the burden on the planet.

Structures which by their form carry their loads principally by direct compression or tension, offer the opportunity of minimum embodied energy. Indeed conscious choice of their form can facilitate natural ventilation and the use of transparency, translucency and reflectivity of structural membranes provides opportunities for natural lighting.

The techniques of form finding and analysis for air supported structures tents and cable nets, gridshells, stone vaults and shells have developed in the past 20 years from largely geometric or physical model, through to finite elements to real time modelling. Documentation for construction has improved from largely draft and drawn instruments to CAD and CIM delivery. The use of robotics for their construction is also now a possibility.

In tensile structures, improvements in microprocessing of form finding and analysis and patterning allow the detailed study of surfaces underload leading to flatter structural surfaces as at RSSB and for the Millennium Dome at Greenwich UK. This has been accompanied by Technical advances in the specification of the physical characteristics of modern tensile membranes. Most recently the use of foil cushions has provided light, transparent, insulating roof surfaces as at Eastleigh Tennis Club, Hampshire UK and other similar projects, providing the opportunity of the admittance of a full spectrum of solar radiation into the proposed enclosure.

Even hi-tech structural membranes need a primary structure for support for spans beyond 16-20 metres. The radial cable structure for the 320 Ø Dome at Greenwich and its 12 100m high masts embody 15kg/m^2 of structural and 1.5kg/m^2 of structural membrane in providing a 'naturally' assisted ventilation scheme within the 80,000m^2 translucent envelope.

Timber Grid shells offer the opportunity of engineering 'free form shell roofs' with little embodied energy. Following the exemplar of Mannheim Grid shell (1975), the grid shells at the Earth Centre at Doncaster, and for the Weald & Downland Museum use of single and double head shells respectively to create enclosed space. One is primarily sculptured the other for a naturally empered workshop for the repair of historical timber trusses.

Once again CAD-CIM techniques are enabling the construction of major vaulted forms in steel, glass and reinforced concrete. The conoidal vault spanning a maximum of 21m over the Maths Centre for Cambridge UK is a composite construction of prefabricated structural steel plate girders and beams encased in reinforced concrete to support a turfed roof of what is an elevated garden. The banquet hall for the Al Faisaliah complex has a number of wishbone shaped arches and r.c. beams to cover 63 x 81m space beneath the landscaped plaza. This provides both an expression of the architecture and the conduit for ventilation and lighting strategies.

Currently 43000m^2 of uninterrupted 3D flowing reinforced concrete shell forms on 33 1.5 x 3.02 piers is being design to create the naturally lit new Hauptbahnhof for Stuttgart, Germany. The platforms are located 12m below the historic Schlossgarten, right in the centre of Stuttgart adjacent to below and parallel to the existing listed Bonatzbau.

The paper has been written to stimulate continuing evolution of lightweight and longspan structural forms resulting from research at University of Bath, and elsewhere and from a number of projects currently being designed by Buro Happold as engineers with a wide range of international designers and constructors.