Most of the structures Gurit are asked to engineer involve the usual requirements for stiffer, stronger, lighter and lower cost structures, so it was interesting to be challenged by Ron Arad to produce instead a very flexible structure.

His idea was to produce a very slender column 50m high that would move “interestingly” in even the lightest of airs. The structure was to have an array of high intensity lights at the top, forming either words or interesting flashing sequences at the top and was to be positioned on the Riverside development at Canary Wharf, London.

It is one thing to produce a freestanding mast 50 m high. It is a more interesting challenge to make it move as much as possible in light winds while ensuring that it will survive the gusting winds generated between the tall buildings that make up the Canary Wharf and Riverside developments.

Generating the maximum movement at low wind speeds requires low bending stiffness for the mast. Slender flexible masts can fail by buckling under their own weight even without any wind loads. The aim of our design was to generate the maximum wind movement by designing the mast to be close to buckling, while maintaining the minimum acceptable safety margins on buckling.
Surviving High Winds

Designing the mast to survive high winds required a different strategy. The high flexibility of the mast is a positive advantage in this case since the drag loads cause the top of the mast to bend over a considerable distance and trail off downwind, just like a blade of grass in the wind.

It is the reduction in effective height and frontal area that keeps the maximum bending loads low. This is one situation where adding more material would stiffen the mast, increase the bending loads and, probably, result in the strength margins on the mast being reduced.

Various studies were undertaken at a preliminary stage to check the feasibility of the design ideas. What we were trying to achieve was a balance between the self-weight of the mast, the amount of drag generated in light/heavy airs and the stiffness and strength of the mast.

Very careful tailoring of the laminate stiffness, through material type and orientation, coupled with optimisation of the geometry, in conjunction with the designer, was therefore required.

This led to a design with a base diameter of 400 mm and a top diameter of 80 mm with an approximately linear taper over the height. The materials selected were glass and epoxy with some UD carbon tapes used to tune the final design.

Mast Anchorage System

The mast is anchored to the ground by twelve bolts fitted through tubes which are bonded around the base of the mast. These bolts are anchored into a hinged steel plate, which allows the mast to be lowered for maintenance if required. The complete anchoring system is fitted below pavement level to provide the impression that the Windwand sprouts directly from the earth.

Analysis of the mast shows that the tip moves as much as 4 m off upright in 11 mph winds and in storm conditions the mast tip will trail downwind as much as 26 m. The extreme flexibility of the mast was evident during its installation. When the mast was lifted at its centre of gravity, approximately 15 m. from the base, the tip did not leave the ground until the C of G had been lifted over 9 metres.

The mast was installed at Westferry Circus in the Canary Wharf development in mid December 1999 and has already experienced several periods of high winds. The architects Ron Arad and his associate Barnaby Gunning have both expressed their satisfaction that the movement of the mast has amply fulfilled their “interesting” criteria.

Aerodynamic Effects

As the aerodynamic effects of the wind on these types of structures are not well documented, a review of the basic wind calculations was undertaken by BMT (formerly National Physical Laboratory, Teddington) to provide increased confidence in the basic design. Composite construction in this particular application offers some considerable advantages over the use of metal, firstly in providing a laminate with high allowable strains, and secondly in allowing the fatigue life of the component to be maintained whilst achieving large deflections. As part of the assurance system the laminate incorporates fibre optic sensors which allow the strain in the mast to be monitored during or after a storm.