

Greenwich Maritime Bronze Cone

The Greenwich Maritime Bronze Cone houses the new Peter Harrison Planetarium at the Royal Observatory. The planetarium lies below ground, with the bronze cone rising above ground level, encompassing the dome of the planetarium.

The cone is a pure geometric form. It is tilted with one side pointing directly upwards, and the opposite side angled at 51.5 degrees, the angle corresponding to the latitude at Greenwich. The length of the longest, slanting side is aligned with the meridian (zero degrees longitude), and is highlighted with a groove in the cone surface, providing a sighting line for the North Star. Bennett Associates involvement included:

- Creating the CATIA model of the bronze cone and supports, used to produce detailed drawings for the manufacture and construction of the full cone structure.
- Analysing the cone in its surrounding under loads from different wind directions to accurately predict the pressure created on the cone surface, using Ansys CFX to model the fluid movement.
- Using Ansys Finite Element methods to create models of the cone during the different stages of construction, and examine the stresses and distortions under different load cases. The pressures calculated in CFX were imported into the Ansys for wind loading cases.
- Creating detailed models of the flexible supports at the base of the cone.
- Working with the client to produce a method for supporting and positioning the thin bronze panels during the difficult construction and welding processes.

The cone is fabricated from 8mm thick panels of phosphor bronze welded together to give a seamless finish. Phosphor bronze has a high coefficient of thermal expansion. With the dark patinated surface finish, the cone changes temperature quickly under the heat of the sun, and expands as the temperature rises. The Phosphor bronze shell covers a soundproof steel and concrete construction. A flexible support system was required to support the shell off the steel and concrete structure whilst allowing expansion and contraction of the bronze shell without any noticeable distortion.

A range of temperature cases were considered to act on the cone including maximum and minimum temperatures for winter and summer conditions, and also where the cone begins to heat up under the sun. For this last case the differential of temperature over the cone surface was calculated and analysed using the Finite Element model. With uneven temperature loadings, different areas of the cone will expand at different rates, which could cause greater movement of the expanding sections of the shell.

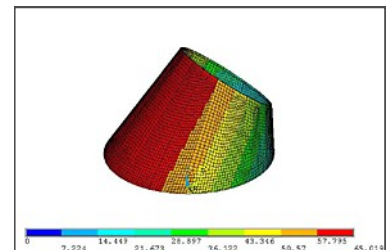
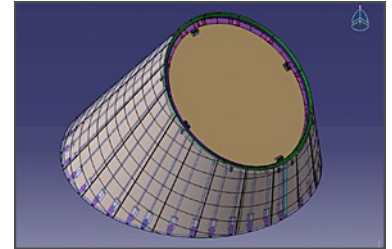
Underneath the bronze surface rubber-tipped ribs run the full length of the structure, attached to the steel and concrete cone underneath. The individual panels rested on these ribs during construction, helping position the panels correctly during the difficult welding processes. As the cone geometry made it impossible to introduce supports during construction that could be removed afterwards, these rubber ribs had to be considered as semi permanent, to degrade over time, and the design of the cone had to consider both the final condition, without the ribs, and the temporary case where the ribs were present.

Under normal operating conditions the rubber will not contact the bronze surface, and the gap between the ribs and the surface will increase over time as the rubber naturally decays away. In all cases no visible distortion could be allowed and load cases where the cone cooled and contracted onto the rib supports needed particular attention.

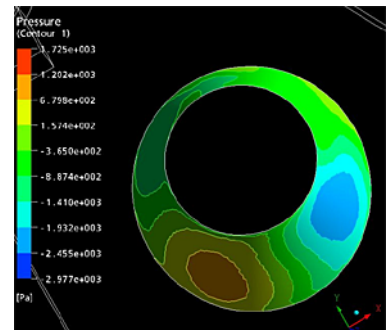
The cone supports needed to be flexible to allow the bronze to expand and contract, but they also needed to prevent lifting off of the cone. When analysing the pressure on the cone surface as wind blew over the distinctive shape, it was found that large areas of suction could occur on the surface, creating considerable upwards forces on the structure.

Flexible, strong supports were fitted beneath the cone surface around the base of the structure at regular intervals, providing a ring of supports. The supports were designed to provide some springiness in the radial direction to allow expansion and contraction of the cone, but also provide firm support in the vertical direction to prevent lift off. The supports are entirely contained by the bronze shell, and therefore cannot be seen from the outside of the cone, creating no detractor from the pure geometric shape.

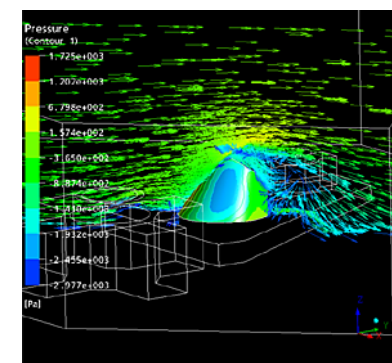
The supports are designed to be entirely invisible to a viewer, under all loading conditions. The carefully designed supports remain unnoticed, however they are the key for providing the smooth, undeformed conical shape, pointing constantly towards the North Star.



Applying temperature loadings - Movement of the cone under temperate gradient



CFX Pressure on cone surface



Calculating wind loadings - movement of air across cone