

## A COMMENT ON TOWERS FOR WINDMILLS

H. P. Budgen

Budgen and Associates  
Pointe Claire, Quebec, Canada

The earliest windmills appeared almost simultaneously in France and England towards the end of the twelfth century. In England windmills were built in grain growing areas, where there was insufficient water-power, and were to be seen in a line east of a line connecting Newcastle with Portsmouth.

No early designs have been found, and it would appear that the parts were set out full size on the workshop floor and made to templates. The earliest accurate drawings of windmills are perspective views shown in Ramelli's "Le Diverse et Artificiose Machine" of 1588. The descriptions given would enable a millwright to make a complete windmill. The earliest published working drawings are those of the fine Dutch mill books, starting with that of Pieter Limperch, a millwright from Stockholm. These drawings were published in Amsterdam in 1785. The earliest mills were very simple, called post mills, and consisted of a box shaped body, supported on a vertical post. The earliest known illustration of the post mill is in the "Windmill Psalter", made in England about 1270. Later the tower mill was developed, and Dutch mill books show this practice before 1700. Thus, towers were incorporated in the main structure. In the fabrication, or design, if any, of these earliest windmills, the main considerations were to accommodate machinery and to hold the wind-shaft, which was usually inclined  $5^{\circ}$  to  $15^{\circ}$  to the horizontal. Generally, there were four sails, but five were used in Leeds, England, by John Smeaton in 1774. Also a few with five and eight sails were tried. Matters of wind obstruction, or 'drag', on towers were not ever seriously considered. Later towers were made of masonry and tapered to the top cap, which was rotated manually at first and later by a small fantail. Towers built in the Caribbean about 1750 were of masonry from local quarries. These towers were profiled in side elevation, much in the form of a parabola, and not as cones, so common in later Dutch and English construction.

Of later years the concept of using windpower more efficiently has lead to compact grouping of machinery, whether for pumping or, more recently, electrical generation, and at the same time to increased speeds and reduced overall swept area of the vanes. Because of this regard to minimize size of the rotor blades and to attain high speeds, much consideration has been given to the economics of tower designs. This has been possible because of the near universal grouping of all mechanicals and electricis in one housing, so that it operates concentrically with the rotor shaft. In such a manner only the conveyance of mechanical, or as may be, electrical energies has to be considered. This can be via a

designed structural frame, a structural steel tube, a concrete or a masonry tower. The requirements for any of these alternatives is dictated by the weight and size of the complete operating system. For small wind turbines manufacturers mount the complete power assemblies on a tube, the height of which is determined according to wind obstructions. Such tubular towers are usually guyed, but the system is arranged so that the whole can be lowered, using a winch, about the fixed baseplate. For the larger power units made, tubular towers are popular, but access has to be provided into or outside of the overhead power system.

For a similar power output consideration, Brace Research Institute designed and built a windmill for pumping in Barbados, which, with a three-vane rotor and a 32-foot swept area, develops a pump water horsepower of 1.16 and 31.3 at wind speeds of 10 and 30 mph respectively. This had a structural tower that could be raised or lowered as required. More recently, Brace Research Institute has designed an improved structural tower to be raised or lowered, a 3-foot diameter standard drawn telescopic tube tower, a parallel concrete circular tower, with a 6.5-foot outside diameter, and one built of reinforced standard concrete blocks with a 6.5-foot outside diameter. All these towers are suitable for the designed mechanical pumping, or electrical generation components designed by the Institute.

In the design of any tower, consideration had to be given to the effect of normal wind forces on the rotor and the tower and to the drag effect of the rotor vanes, and the tower, all create an overturning moment. Circular tubular or masonry towers present a relatively simple aerodynamic solution. This is not the case with lattice structural shapes. Because of this easier approach and because of lower manufacturing costs, the tubular tower now takes precedence everywhere for small and medium sized windmills.

The Brace Research Institute examined concrete, and standard concrete block designs for towers, especially for construction on sites by local labour in developing countries. These designs were found to be cheaper than shop prefabricated steel structures which have then to be freighted to the areas of usage.

Fabricated steel towers cost \$4750 (made in Canada) to which freight must be added. A circular reinforced concrete tower made in Canada costs \$6787, but \$1984 if made in a developing area with lower labour costs such as the Caribbean. A reinforced concrete block tower made in Canada would cost \$5000, but, if made in a developing area it would cost about \$1600. A telescopic 3-foot diameter, reducing to 2-foot diameter, tube which can be extended by two small winches incorporated within the tube, costs in Canada about \$3000.

Thus, on-site construction of towers for medium sized wind turbines, is cheaper when made of locally available materials--largely because of labour costs. For similar constructions in Canada the steel tubular tower is probably the cheapest.