

ANALYSIS AND DESIGN OF A HYPERBOLIC COOLING TOWER

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## I. INTRODUCTION AND SCOPE

The hyperboloid of revolution can be generated by rotating a hyperbola about its directrix. Shells of this type are built throughout the world as cooling towers to lower the temperature of coolants used in electricity generating plants and chemical plants. This type of shell has proven to be efficient for use in reinforced concrete natural draught cooling towers for the conservation and reuse of the coolant (water).

The purpose of this report is to present the solutions for the stress resultants for the membrane and bending analysis and the corresponding displacements for cooling towers under dead load and wind load. Numerical results comparing solutions obtained by membrane theory and bending theory are presented.

## II. REVIEW OF LITERATURE

The first hyperbolic natural draught reinforced concrete cooling tower was designed by Prof. Van Iterson of the Dutch State Mines and installed at the Emma Colliery in 1916 (2). Towers of this type were installed at Lister Drive Power Station in Liverpool in 1925 and since then have become quite common and standard practice in Europe power stations where cooling towers are required. The typical size for old towers is shown Fig. 1. This type of tower has become a familiar sight in the United States with the first tower constructed in connection with a power station in Kentucky about fifteen years ago (1960). These structure sometimes reach over 350 feet in height and have base diameter often over 200 feet.

Immense quantities of water are required for the condensers of power stations, refineries, steel plants, etc. and sites with adequate cooling water are becoming rare; thus there is a need for the development of natural draught cooling towers for cooling and reusing large quantities of water.

The one-sheet hyperboloid is a convenient geometry for cooling towers with its straight-line generators for both structural and thermal reasons:

1. It has been proven (2) that the shear and vertical stresses are reduced by over 50% due to the "hyperbolic" shape of the shell compared with a cylinder of the same height and base diameter. Also this type stiffens the shell against wind force.
2. The momentum of the air entering the shell carries it into the center to form a vena contracta whose diameter depends on the

ratio of tower diameter to height of air inlet.

The other advantages of this hyperbolic concrete tower are (3):

1. Concrete towers are permanent.
2. There are no fans or similar equipment so there is lack of vibration due to resonance of fans and the tower. Therefore, the only power consumption is needed for pumping the water to the distribution pipes.
4. The natural draft towers minimize hazards such as fire, mist, and frozen spray.

Rish and Steel (2) discussed the treatment of the hyperboloid by assuming the shell to be made up of two truncated cones with a cylinder in between. Martin and Scriven (4) and Martin, Maddock, and Scriven (5) presented numerical solutions for dead load and wind load stresses and displacements in a particular shell. Gould and Lee (6,7,8,9) presented the membrane solutions and bending solutions for the stress resultants and displacements in hyperbolic cooling towers subjected to dead load, earthquake load, and wind load. The influence of the various shell parameters on the magnitude of the stress resultants and displacements is studied by these researchers and design tables are given to facilitate the design of such structures.