Wind tunnel research to obtain wind loads on structures.

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Introduction

Wind engineering has developed since the 1950's. It is an applied science, using knowledge from other sciences, such as physics, meteorology, civil engineering, psychology, fluid dynamics, etcetera. The basis of wind engineering were experiments, both in full scale, under real life circumstances, as well as scaled down, in laboratory circumstances, using wind tunnels. Large progress has been made in the development of wind tunnel techniques and, over the last two decades, in the development of numerical techniques (CFD).
Current design coefficients in codes and guidelines are generally based on wind tunnel experiments. Besides that, wind tunnel experiments are used as alternative for codes of practice in cases outside the scope of these codes, or when it is assumed necessary to obtain the wind loading more precisely. This can be based on reasons of safety or economy. This lecture focuses on the application of the wind tunnel for wind loading studies. The lecture will only briefly mention scaling or instrumentation issues. These are covered in another lecture.

A brief history

The earliest attempts to model the effects of the wind on buildings experimentally date back to the 18th century. Models were moved in the air to determine the drag. Experiments where the models were fixed and a fluid was moved (e.g. water or air) originated in the 19th century. Large progress was made by Irminger and coworkers in the early decades of the 20th century. The fundamentals of our current techniques was developed in Göttingen in Germany, in the 30's, mostly connected to developments in aerospace engineering. These experiments, and others done at that time, were performed in flows with low turbulence, without boundary layers. The need to model the atmospheric turbulence properly has lead to the design of so called Atmospheric Boundary Layer Wind Tunnels. Jack Cermak was one of the first to fundamentally investigate these aspects in wind tunnels. In the 1950s, Martin Jensen formulated his Model law, in which the requirement to model the earth's roughness properly was defined. This led to the development of relatively long working sections. In 1965, the University of Western Ontario opened one of the first wind tunnels specially designed for the atmospheric boundary layer. This tunnel is still in use.
Whilst instrumentation, data acquisition and data handling techniques developed drastically over the past decades, wind tunnels are still very much based on the principles developed by Cermak and Davenport.
The development of data acquisition and computing abilities made it possible to handle large amount of data. Modern wind tunnel experiments for the wind loading on buildings use statistical analysis techniques of the measurements to obtain design loads.

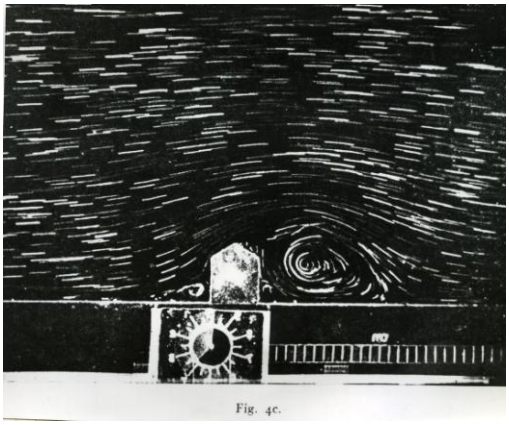


Fig. 4c.

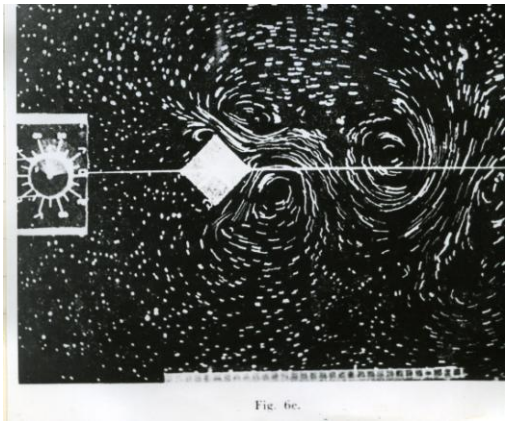


Fig. 6c.

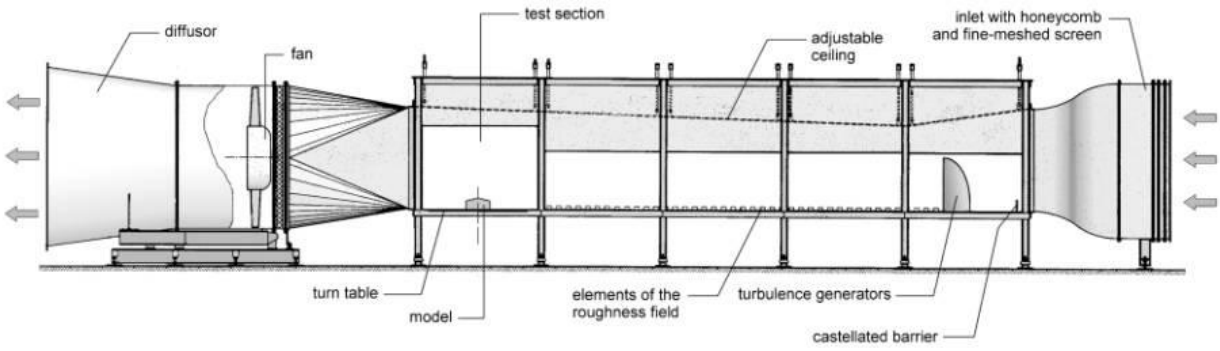
Overview of wind tunnel technique

An atmospheric boundary layer wind tunnel consists of the following elements:

- -One or more ventilators to develop moving air.
- -Devices to 'straigthen' the flow coming from the ventilator before it enters the test section. These devices usually contain a contraction, to accelerate the flow, and one or more honeycombs and directional vanes to make the flow low turbulent.
- -The working section is usually adjustable and contains the model of the building under consideration, and specific features to generate the flow in the atmospheric boundary layer. These features are, seen from upstream:
    - A barrier, or step, at the entrance of the tunnel to generate large scale turbulences
    - An array of spires
    - A large fetch of roughness elements to generate a boundary layer flow.
    - A test section, with a turn table, on which the model is places
- An outlet of the flow

Depending on the type of wind tunnel, the flow is recirculated (closed section tunnel), or connected to the outside world (inside or outside), for an open section tunnel. Open section tunnels can have the fan places before or behind the test section.

Variations in wind tunnel technique may be adjustments to be made to the ceiling, the positions of the roughness elements. At the Boundary Layer Wind Tunnel Lab in London, Ontario, adjustable roughness elements have been installed. Some wind tunnels have walls in the test sections which are partially open, to minimize blockage effects.



View of the wind tunnel of the Ruhr University in Bochum, Germany