An Open Jet Wind Tunnel at CSIRO, Australia

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ABSTRACT

Water penetration through building envelopes is of grave concern to architects and structural engineers. To test building facades for water penetration, a facility is required where extreme weather conditions (both wind and rain) can be simulated. Such a facility is being established at CSIRO, North Ryde in Australia. It is an open jet wind tunnel that uses the high speed airflow from a turboprop aircraft (Lockheed C 130 Hercules) engine to simulate cyclone (typhoon, hurricane) force winds. Samples with cross sections up to about 8 metres by 8 metres can be placed downwind of the engine and tested. It is expected that wind speeds up to 270 km/h can be obtained in the test section. A complete description of this facility and its capabilities are documented in this paper.

INTRODUCTION

The basic requirements of the envelope of a building are to provide a comfortable environment for the occupants and to protect them from natural elements such as rain, wind, hail and fire. The building envelope should also be able to control the amount of light and air entering the building. Ensuring weather-tightness of a building envelopes is a complex problem. Freeman (1975) notes that rain water seepage through building facades accounts for about 40% of moisture related problems in buildings. A poorly designed or constructed building envelope may allow rain water to seep through and reduce the efficiency of the envelope, degrade the aesthetics and lower the comfort level of the inhabitants. As the cost of the building envelope is a substantial fraction of the total building cost, the maintenance or replacement of building envelopes can involve substantial amounts of money, energy and time.

Adequate weather-tightness can be incorporated in the building envelope during the design stage if long term weather data is available for the building site. However, a reliable weather database alone is not enough to ensure that the envelope is leak-proof. A building envelope that performs well for one combination of wind speed and rainfall intensity can be inadequate for another such combination. Further, a well designed envelope can also perform poorly when the techniques used for its construction are inadequate.

To ensure weather tightness, a sample of the envelope must be tested under simulated dynamic weather conditions. Such a facility is being established at the Division of Building Construction and Engineering, CSIRO in Australia. In this paper, a brief background and a detailed description of the open jet wind tunnel facility is presented. It is specially designed to study the wind resistance and water penetration resistance of building envelopes under dynamic wind and rain loading. It can also be used for many other applications that can not be carried out elsewhere.

METHODS OF TESTING

There are several methods available for evaluating the wind resistance and water penetration resistance of building envelopes. One such method is the use of a small aircraft engine facility which is relatively easy to set up and has been used to test building components both in Australia and overseas over a long period of time. However, the capabilities of small aircraft engines are limited, particularly in terms of mean wind speeds that can be generated and the size of the specimen that can be tested. The open jet wind tunnel will allow large size specimens to be tested at wind speeds comparable to that of cyclones (hurricanes), and with a large turbulence length scale and intensity.

Another popular method is the pressure chamber type testing. The details of this method are outside the scope of this paper. The prime advantage of the pressure chamber test is that it can be set up on the faces of existing tall buildings that are having water penetration problems or samples of new facades. It can pick up failures due to the ageing of materials and joints. One major disadvantage of the pressure chamber type of test is that it cannot model the effect of pressure variations along the building surface. The variable pressure is an important parameter that can result substantial water flow through the facade cavity. Only a large dynamic facility such as the open jet wind tunnel can produce pressure variations similar to that occur in real life.

BACKGROUND

The need to evaluate the effects of weather on buildings and their components on the basis of performance was recognised as early as 1947 by the then Experimental Building Station (EBS) at North Ryde. A controllable high speed wind source and a series of combination sprays were required for this purpose. In order to minimise establishment costs, the EBS purchased a Hawker Sea Fury aircraft, a combat fighter used by the Australian Navy in the Korean War. This was used as the high speed wind source. The Sea Fury had the outer sections of the wings removed to stop it from flying. The tail section was held to the ground to maintain the flight angle of the fuselage for greatest efficiency of air flow. This facility was used for blowing high speed air together with sprayed water at building products and assemblies to test their weather performance (Fig. 1). Due to several serious mechanical problems, the Sea Fury was taken out of operation and is now a historic exhibit at the Australian War Memorial.

The Sea Fury is being replaced by the open jet wind tunnel. This new facility uses an Allison T56-A11 turboprop engine (3600 HP) from a Lockheed C 130 Hercules transport aircraft. The air volumes and wind speeds of the Allison engine are very much larger than that of the Sea Fury.

While the major DWTF facility is under construction, a Pratt and Whitney R2800 piston driven aircraft engine (2400 HP) was set-up on a cantilever test frame (Fig. 2) to meet the immediate building envelope testing demands. The R2800 facility is being used to evaluate the adequacy of building components such as smoke and heat release ventilators, roofing hardware and awnings.

OPEN JET WIND TUNNEL FACILITY

As mentioned before, the main component of the open jet wind tunnel is the Allison T56-A11 turboprop engine from a Lockheed C 130 Hercules transport aircraft. It is mounted on a steel frame shaped like the letter **A**. This, in turn, is enclosed in a circular steel casing with inside diameter of 5730 mm and an outer diameter of 6000 mm. Both the **A**-frame and the circular casing are heavy and rigid thus minimising vibration when the engine runs.

The Allison T56-A11 engine (Fig. 3) has a 4622 mm diameter variable pitch three-bladed propeller which runs at a constant rotational rate. Noise is generated by the propeller, the compressor and turbine blades and the exhaust chamber and it is a potential problem. In order to reduce the noise, the engine exhaust was fitted with a tuned muffler. Also, a layer of noise absorbing foam, held in by perforated steel sheeting with in-built tuned cavities, was added to the inside of the steel casing. This arrangement is expected to significantly reduce the noise.

The **A**-frame and the circular steel casing rest on a base frame. There are four cells (or rooms) attached to the base frame. These sit on vibration dampers which negate most vibration generated by the engine. The rooms are called the Control Room, Bottle Room, Fuel Room and Electrical Room. The Control Room is fully lined with sound absorbing material (similar to that of the steel case) and contains instruments related to the control of the engine, fuel, electrical power, and air, nitrogen and CO_2 lines. A video terminal, which is directly connected to a closed circuit video camera mounted at the top side of the outer steel casing, is also located inside the Control Room. They will be used to monitor the engine and the test specimen while the testing is in progress.

The Bottle Room is used to store air, nitrogen and CO_2 bottles. The air bottles supply compressed air to turn the engine over when starting until the fuel takes over. The nitrogen bottles feed nitrogen into the engine nacelle in the event of a fire or an overheat condition being detected within the engine cowling. The CO_2 bottles are kept in this room for controlling external fires.

The Fuel Room contains a large tank of JET A type fuel (a high quality kerosene) and associated fuel pumps, filters, valves and pipework. The Fuel and Electrical Rooms are separated by a fireproof wall.

The facility has the following electrical power circuits: 240V at 50Hz; 415V at 50Hz (3 phase); 200V at 400Hz (3 phase); 105V at 400Hz; 26V at 400Hz; and 28V DC. The Electrical Room contains a 3 phase 400 Hz motor/generator for converting the normal 50Hz supply to 400Hz. The Allison aeroplane engine also has a 400Hz generator. Two independent power supplies are necessary for safety reasons.

The entire facility (Fig. 4) is mounted on rails so that it can be moved laterally. This arrangement will eliminate the time delay between successive testings. After the completion of a test, the facility could be moved laterally to another location where a specimen is already mounted on a test frame, ready for testing.

The open jet wind tunnel is made in modules so that it can be dismantled and moved to other sites.

CAPABILITIES AND ADVANTAGES OF DWTF

It is hoped that the open jet wind tunnel will be capable of generating turbulent flows at speeds in excess of the design wind speed for normal structures at any place on earth. The National Hurricane Centre in Miami estimated (from air pressure) the maximum sustained wind speed of "Hurricane Andrew" to be 232 km/h. Wind speeds up to 68 m/s (245 km/h, 153 mph, 132 knots) are expected to be achieved at the test section.

Test specimens up to eight metres high by eight metres wide can be tested. This allows, for example, the wind pressures on three storeys of a high rise building to be estimated. In addition to testing building envelopes for wind resistance and water penetration resistance, there are several other applications of diverse nature for this facility.

The airflow will have a high turbulence intensity and large length scale. This is a significant advantage as large scale turbulence, which is a feature of the atmospheric wind, is not easily reproducible in wind tunnels. Because of the combination of high speed wind and large length scale, the Reynolds number of the flow will be large which is, once again, normally difficult to achieve in a wind tunnel.. These features make the open jet wind tunnel highly suitable for strategic research.

CONCLUDING REMARKS

The mechanical aspects of open jet wind tunnel have been completed and the electrical and instrumentation areas are being worked on by specialist aeronautical engineering technicians. All this work has been done by the DBCE without any corporate sponsorship. It is expected that the remaining work will be completed and the facility fully commissioned soon.

REFERENCE

Freeman, I. L. (1975), "Building Failure Patterns and their Implications", BRE Current Paper No. CP 30/75, Building Research Establishment, Garston.

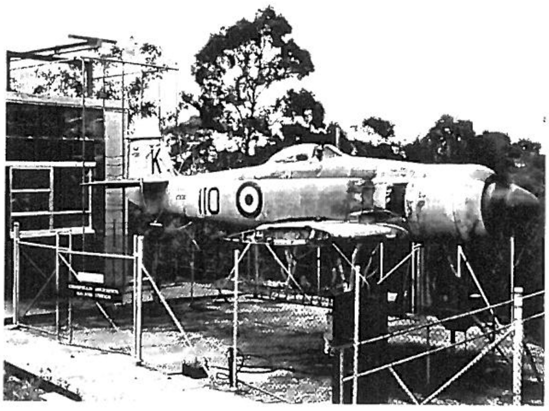

Figure 1 A photograph of the Sea Fury being used for a water penetration test.

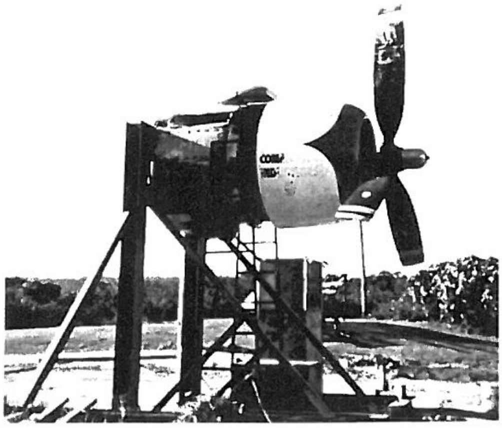

Figure 2 A photograph of the Pratt and Whitney aircraft engine.

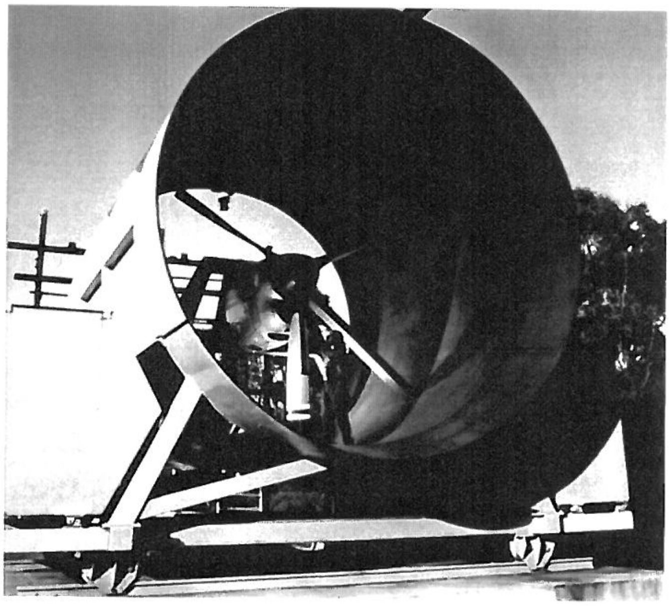

Figure 3 A photograph of the Allison engine mounted on the A-frame.

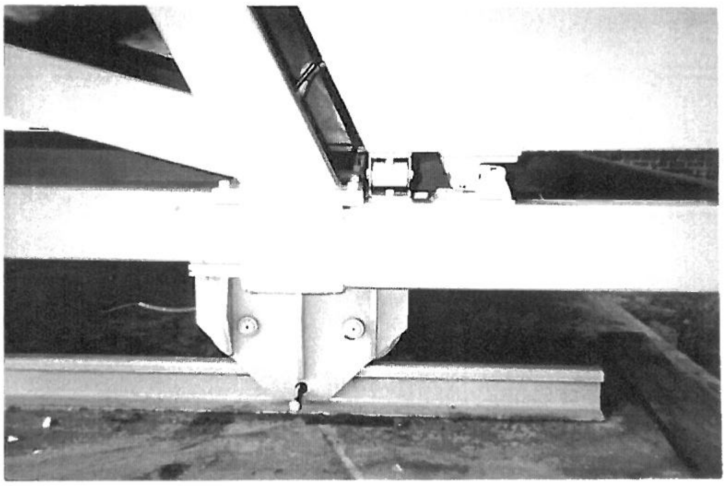

Figure 4 A photograph showing the rails on which the open jet wind tunnel is mounted.