James Cook Cyclone Structural Testing Station

by Greg Reardon, Technical Director

The Cyclone Structural Testing Station has provided international leadership in the design of cyclone resistant construction details, methods and systems. The Station's strategic location in Townsville has enabled it to serve not only Australia and North Queensland but also most other cyclone prone regions throughout the world. The Station's mission is delivery of quality research programs, testing and technical advice, leading to effective building practices that minimise loss and suffering as a result of severe wind events.

History

In the mid 1970s, Professor Hugh Trollope AO, then Professor of Civil Engineering at James Cook University, and Mr Theo Wilkinson, then Managing Director of Monier Colourtile, recognised the need for the establishment of a small research unit to investigate the effects of wind on low rise buildings. It was obvious after cyclone Tracy devastated Darwin that there was not an adequate source of practical information on the likely performance of houses subject to severe wind forces, nor on ways of preventing future wind damage. They decided to overcome this by establishing a unit at James Cook University to research these problems. The university had just built a wind tunnel and had established an international reputation for its work in wind engineering.

James Cook Cyclone Structural Testing Station commenced operations on 1 November 1977. It was established to fill a need in the building industry for a specialised research unit to concentrate on wind effects on low rise buildings, and to provide industry with an independent centre for the testing of building products and the development of testing techniques. Its charter is not restricted to cyclone winds.

The Station now operates as a unit within the School of Engineering at James Cook University, Townsville. Although it was established under the Constitution of the James Cook University it has managed to achieve its own identity through its research and testing programs and through the guidance of its very active Management Committee. It is dependent upon the School for accommodation and the use of structural engineering test facilities, but otherwise it is self funding.

Research and development

The Station is probably best known for its house testing research program. So far it has tested to destruction seven new houses and one old one. The new ones were a traditional tropical high set house, three brick veneer houses, two of light gauge steel construction and a timber framed one with plywood cladding sent from the Pacific island kingdom of Tonga. Some were tested for cyclonic wind forces while others were tested for Sydney, Melbourne or Brisbane wind climate. These and other results from the test series have been published nationally and internationally and made available to authorities for inclusion in building regulations and Australian standards.

As another research project, the Station has investigated the performance of high strength thin metal roofing subject to load cycling, as occurs during a tropical cyclone. Many of the Station's publications in recent years have addressed this complex problem. In collaboration with others it is developing a new test procedure to simulate this cyclic loading effect.

The Station has maintained a high practical content in its research program. Some of the more practical topics researched in the 20 year period include the performance of batten/rafter joints, the corrosion of roofing screws, diaphragm action of ceilings, bracing strength of roofing, ribbon plate timber framed construction and roof truss hold down against high uplift forces. The results of these have been published in the Technical Report series and are used by industry.

The Station has also conducted damage investigations after tropical cyclones hurricanes. These have been conducted at various locations in Queensland, Northern Territory and Western Australia, as well as Tonga, Vietnam and USA. The most significant of these would have been its investigations into damage to houses in Miami after Hurricane Andrew in 1992.

Over the past two decades, there has been a much greater awareness of the need to understand the risk of occurrence of extreme events and to predict the likely consequences of that occurrence to a particular community. The Station has collaborated with the Bureau of Meteorology and Queensland Emergency Services in making an extensive assessment of the likely damage to Queensland coastal communities from severe cyclone winds. The Station has also consulted in risk assessment studies.

The Station has been very active in the formulation of building and structural engineering codes, building regulations and advisory publications. It has been represented on Australian Standards committees for housing, house components, housing performance and loading.

The Station has issued nearly 500 confidential reports to industry on the performance of products subjected to simulated wind loads. The most common requests are for pressure testing of roof and wall cladding and for racking of bracing walls, mostly in cyclic loading for cyclone prone regions. Some of the more unusual ones have been withdrawal strength of ground anchors, on-site lateral loading of balustrades, testing battenless roofing, checking prestress in guy cables and lateral loading of fences. Risk assessments and terrain categorisations have also been conducted.

Testing for industry

The Station provides a service to the building industry as an authority for testing the effects of wind forces on buildings and building components. Where standard test methods are not available the Station has developed its own techniques to accurately simulate the effects of wind pressures on structural elements. It has established itself as the leading independent testing authority in Australia for wind effects on buildings and components.

a. Structural

Structural testing is usually required when either the form of loading or the structural element does not comply with the relatively simple rules that govern engineering design. Cyclic loading of roofing is an example where the effects of both the loading and the structural resistance are not covered by simple engineering design. Normal structural engineering design theories do not cover the effects of repeated loading, nor do they adequately allow for a structural element that changes the shape of its cross section as transverse load is applied.

The Station has developed techniques for accurately simulating the effects of wind on buildings and components. Some of the structural tests it conducts are:

- static or cyclic racking and uplift on full scale buildings
- cyclone wind risk assessment of communities
- determination of terrain categories
- static or cyclic loading of roof sheeting, roof tiles, wall cladding, and joints
- static or cyclic racking of bracing walls and ceiling diaphragms
- static or cyclic uplift on walls
- static or cyclic flexure of walls
- water permeability of walls
- withdrawal strength of fasteners
- pressure loading of glass
- debris impact on screens
- lateral loading of walls and fences.

b. Wind tunnel

In structural engineering, wind tunnel tests are usually needed for slender structures or components where their interaction with wind results in additional loading. A wind tunnel can also be used to determine ventilation of buildings and plume dispersion effects. The following services can be provided by the Station:

- determination of structural and overturning loads
- determination of cladding pressures
- studies of pedestrian wind comfort
- determination of dynamic forces
- studies of building ventilation
- studies of environmental air quality.

The future

What will the Station be doing in 10 years time? Which way should it be directing its research programs?

Assuming that its excellent relationship with the building industry and James Cook University continues, the following areas of research are logical extensions of the Station's aim to conduct quality research to minimise loss as a result of severe storms.

Whilst the house testing research program has made an extensive contribution to the knowledge base of how houses perform in high winds, emphasis is likely to change to computer based analysis. The advent of bigger and more powerful computers and analysis programs has opened the way for more comprehensive analyses of complex structures such as houses. These were not available when the house testing research program was initiated. Items identified in the program, such as the sharing of load by adjacent members, the significant contribution to lateral strength and stiffness by the internal lining materials and some external claddings acting as diaphragms and the extraordinary contribution of the plaster cornice will be accounted for by complex super elements within a finite element analysis. This may lead to the identification of other force paths or contributing systems too subtle to be identified in the testing program. It is a formidable task to mathematically describe the action of all of the small elements that constitute even a simple house, and to determine their interaction and integration to become a structure capable of withstanding severe wind forces.

The Station is a leader in research into the strength and performance of roof and wall cladding materials. In 1998 it plans to commission an air box test facility that will herald a new era in its research and testing of cladding. With the free air facility, pressure can be applied to all of the re-entrant angles and flutes of a ribbed cladding profile. For cases where building paper or sarking is not used directly under the roofing the free air system gives a better distribution of pressures on profiled cladding than an air bag test system.

An extension to the free air system is to be able to apply abrupt pressure changes to the cladding, as can occur during a wind storm. The ideal situation would be to have the capacity to apply pressure fluctuations in accordance with a pressure trace measured on a building during a real wind storm, or from wind tunnel tests. The only device currently available with this capability is the very expensive BRERWULF system developed by Building Research Establishment, UK.

Since its commissioning in 1977, the boundary layer wind tunnel at James Cook University has been used in the areas of wind loads on buildings, pedestrian comfort, building ventilation and atmospheric air quality. Data from wind tunnel research on domestic low-rise buildings have been used to develop standards to improve construction methods. The growth of computer modelling in wind engineering will require increasing amounts of experimental data for calibration and validation. Such data obtained from full scale and wind tunnel studies will also be used in updating and standardising codes globally. Wind tunnel studies will continue to be an efficient research tool with continually improving electronic technology.

The Station is developing closer relations with Asia and Pacific Rim countries. It has already established close relationships with Fiji and assisted in the design of 'hurricane houses' for Tonga in 1984 by testing one of the prototypes. The two United Nations consultancies, India in 1993 and Vietnam in 1996, demonstrated that those countries need assistance to reduce hardship for people as a result of damage to houses and buildings during tropical cyclones or typhoons. There are various levels at which assistance can be given. Education programs are needed, extending all the way from professionals such as architects and engineers through to supervisors and builders in villages. Interchange of research personnel between institutions in Asian countries and those in Australia has been proposed. Collaborative research programs can also help the developing countries. It is planned to continue and expand these activities.

A greater emphasis is being placed on the assessment of vulnerability of communities to natural hazards. Local government authorities, emergency services and the insurance industry all have an interest in being able to predict the likely performance of buildings in a township threatened by a severe hazard. These assessments are very dependent upon the experience and expertise of those conducting them. In the field of wind engineering, the Station has built up extensive experience from its research and damage investigations. The development of risk assessment programs is seen as an area where the Station can contribute to the reduction in the effects of a severe wind storm on a community.

The development of retrofitting techniques to improve the strength of older buildings is not new. Many houses in Darwin were fitted with external strengthening devices after cyclone Tracy. But there has been little evidence of those techniques being put to use since. The Station could develop a suite of different methods of improving the structural strength of older houses. Different solutions would be required for different forms of house construction.

Whilst verifying the validity of the Greenhouse Effect is the role of meteorologists and scientists, the Station must be aware of the likely consequences in respect of tropical cyclones and thunderstorms. If the oceans do warm up, and the region of influence of tropical cyclones is increased, will their frequency increase also? Will the intensity increase as well or is there a limit on the amount of energy available to sustain cyclone activity? The Station will need to stay up to date with all the likely scenarios so that it can advise industry and government on possible consequences.

In summary, future research programs will include numerical analyses of houses, extensive wind tunnel studies, development of new testing techniques and cyclic loading regimes and practical investigations into the performance of structural elements.