Understanding the Effects of Severe Windstorms on Buildings

Dr John Ginger

Scientia

UNDERSTANDING THE EFFECTS OF SEVERE WINDSTORMS ON BUILDINGS

As natural disasters are affecting an increasing number of people worldwide, risk mitigation by design is of primary concern to engineers. One of those engineers is **Dr John Ginger,** Professor of Civil Engineering and Research Director of the Cyclone Testing Station at James Cook University, Australia. His team's research focuses on the effect of catastrophic winds on buildings – principally, the effect of internal pressure and its contribution to the overall wind loads and the resulting structural response. Their work has been pivotal in developing improved building protocols.

Understanding Wind Loadings and Building Response

Strong incoming winds exert a large pressure on the external surfaces of a building. If a door or window is compromised during a storm, the wind swiftly enters the building. Once inside, the air pushes against the internal walls, exerting a sizable force, creating what is known as 'internal pressure'.

Internal pressure is a key contributor to building damage and the resulting losses. At the very least, internal pressure can cause the envelope, such as wall cladding and roof sheeting, to be dislodged, 'opening the door', as it were, to more severe structural damage. Therefore, understanding the generation of internal pressure in buildings during storms, and the factors that contribute to its magnitude, is vital for preventing damage and mitigating risk. Specifically, such awareness would improve the initial design and construction of buildings and infrastructure.

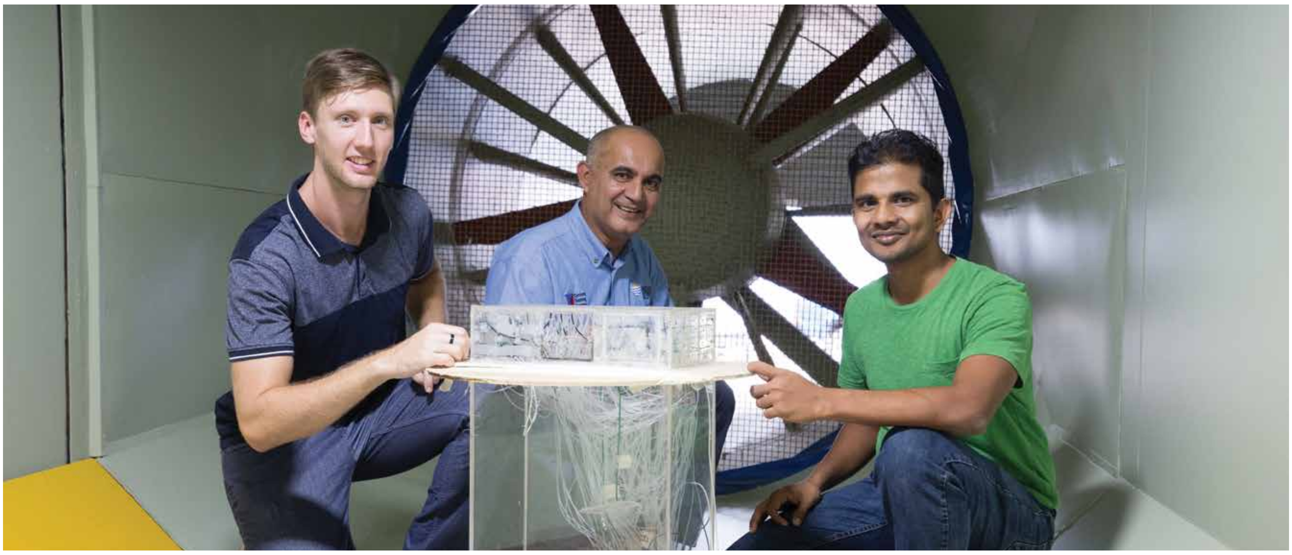
Dr John Ginger of James Cook University, Australia, has devoted much time and energy to gaining this understanding. He and his colleagues have used a range of different testing procedures in their research, including wind tunnel model tests, computational methods and most importantly, full-scale studies. Their aim is to gain insight into wind loading and structural response during catastrophic wind events. These insights, in turn, can be of use in developing of design protocols and building standards.

As was highlighted by Dr Ginger, 'numerous post-windstorm damage investigations have shown that large internal pressure (caused by a dominant opening formed by a breach in the building envelope) is the main cause of building damage, at wind speeds less than design.' The fact that buildings are being compromised during severe weather events, at wind speed levels lower than what has been deemed to be safe, is indeed concerning. But with reliable data, a better understanding of the factors affecting internal pressure, and robust mathematical techniques to estimate internal pressure, this situation could be improved, and the associated risks mitigated.

Factors Effecting Internal Pressure

Of particular interest to Dr Ginger is how the size and location of the dominant openings (such as a broken window, open roller door or breached wall panel), and building volume affect internal pressure. In a 2010 research project, using wind tunnel tests on a model building, Dr Ginger and his team were able to deduce clear relationships between external and internal pressure and dominant opening size and building volume. Dr Ginger suggests that buildings may at times experience internal pressures equal to, or greater than, external wind pressures during a severe windstorm.

‘My research objectives are to undertake studies which provide practical outcomes that benefit the community, whilst retaining an academic interest in the project. In each project, I aim to provide a better understanding of the wind loading process and structural response.’



From left to right: Mitchell Humphries, John Ginger and Geeth Bodhinayake

There are several other factors, such as flexibility of the building envelope, approach turbulence, and flow patterns, that contribute to the magnitude of internal pressures. Background porosity is another major consideration. Background porosity refers to the leakage, or escape, of wind out of openings in the building envelope. As was highlighted in a research paper of 2013, previous work had described in detail the internal pressure response of a *sealed* building with a dominant opening. But buildings will, due to other openings and air leakage paths, have varying degrees of background porosity. This factor had not been taken into consideration in previous research. Dr Ginger’s study found that background porosity is an important factor in determining internal pressure and should be considered. Better still, his team demonstrated that background porosity can be factored into the mathematical relationships that had been devised to estimate total internal pressure.

In fact, by reflecting upon previous research, and by conducting their own experiments, Dr Ginger and his colleagues were able to develop detailed mathematical analysis methods to estimate the internal pressures experienced by buildings during significant wind events. These formulae incorporated the many factors that Dr Ginger’s team, and others, had studied, and would be key in applying the lessons they had learnt to real-world applications.

Improving Australian Building Standards

Dr Ginger’s work with his team at the Cyclone Testing Station will result in improving Australian building standards, both significant and timely. In a 2015 document, prepared for the Bush Fire and Natural Hazard’s CRC, Dr Ginger and his team wrote, ‘Internal pressure design in Australia is currently based on limited, simplistic analysis’. They also commented on the effect this was having on building design: ‘The limited design scenarios and lack of understanding by some engineers has led to a range of internal pressures being used by structural designers, with the temptation to use lower internal pressures, leading to lower cost design’. Of course, the consequences of this could be disastrous.

The team was driven to conduct both full-scale and wind tunnel testing, and to determine the internal pressures that industrial buildings may be subjected to. They wanted to get a complete understanding of the effects of building volume, flexibility, porosity, and the size and shape of openings on internal pressures, and then compare these to the specifications in current standards. In summary, their results showed that the Australian wind loading standards can underestimate internal pressure exerted on building envelopes by up to 10%.

There were further insights gained from experimentations carried out in since 2015. It became apparent that a typical industrial building, due to its simplicity of design, is an excellent tool for studying wind loadings. In addition, tests carried out on such-like buildings would also lay a foundation for the testing of more complex, multi-levelled structures. Furthermore, the study of industrial buildings can be used to easily transition between experimental findings and implementation into codes and standards.

Working with Local Companies to Improve Building Design

Dr Ginger sought to work with local companies to improve their practices too. Specifically, he wanted to optimise the design of steel, industrial-type buildings to minimise wind induced damage. A project between the Cyclone Testing Station at James Cook University, where Dr Ginger conducts his research, and the Australian Steel Institute was initiated to provide tangible benefits to the community in terms of more resilient, optimally designed buildings. The results of this research are being applied to the relevant codes governing the construction of steel industrial buildings, for example, improving both design and construction procedures.

Improved steel industrial building design may also hold out financial benefits. Given that a reduction in internal pressure of 50% will reduce building materials and cut costs by an estimated 20% on the construction of a typical industrial building, there are significant potential savings to be made, with the savings being passed on to consumers. Interestingly, approximately 8000 sheds are sold in Australia each year in high risk, cyclone affected areas. With improved practices, Dr Ginger estimates an average saving of 7% on the wholesale costs associated with shed production. This has the potential to save over five million Australian dollars each year in cyclone affected areas alone.

Offering Expertise in Post-Disaster Assessments

In 2011, the severe tropical cyclone 'Yasi' struck far-northern Queensland in Australia, making landfall near Mission Beach, 138 kilometres south of Cairns, between midnight and 1 a.m. on Thursday, the 3rd of February. The cyclone was one of the most powerful storms to have hit Queensland in recorded history – causing widespread damage and devastation. Some estimates put the total damages resulting from the event at 800 million Australian dollars. Approximately 1000 people reported serious damage to their homes, while the net loss to agricultural production was estimated to be 300 million Australian dollars.

Dr Ginger and his team from the Cyclone Testing Station carried out post-disaster investigations after cyclone Yasi. They also conducted similar investigations following other severe Australian windstorms such as cyclones 'Vance', 'Larry' and 'Debbie'. Given that wind is one of the main agents of destruction during severe weather events, their expertise in the field of wind engineering proved to be invaluable. Dr Ginger and his team have produced several reports that have been used by regulatory authorities and government departments to develop a range of responses for improving building resistance to windstorms and protecting communities.

Clearly, Dr Ginger's work has benefited the global community in many ways. And the knowledge, insights and expertise his team has shared will only continue to do so. Their research has contributed much to understanding how to reduce the damage caused to buildings and infrastructure during times of natural disaster.

Meet the researcher

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Dr John Ginger completed his PhD is 1993 at the University of Queensland with a thesis entitled 'Characteristics of Large Fluctuating Pressures in Regions of Flow Separation on Roofs'. This study of the effects of wind pressure on buildings would prove to be an important feature of his research. In fact, Dr Ginger has been involved in research, testing and consulting in the field of wind engineering for several years. He has made significant contributions to the understanding of wind loading and structural response, especially during extreme weather events. His insights have been invaluable in the development of improved building standards in Australia and across the globe. He presently serves as a Professor of Civil Engineering at James Cook University (JCU), and is the Research Director of the Cyclone Testing Station (CTS) in Townsville, Australia, which he joined in 1996.

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FURTHER READING

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