Winds of change

Professor Mark Sterling discusses how it is only by understanding the fundamental nature of wind flow that novel approaches to structural challenges can be developed

What do you hope to achieve through your research interests and ambitions?

I am motivated by understanding the effects of strong winds on the world around us. My research has led me to look at the interaction of winds with a range of different elements, including cereal crops, people, vehicles, buildings and, lately, cyclists. In order to be cognisant of these interactions, I think it is very important to understand the physics of wind and, in particular, flow structures. Only by understanding the fundamental nature of the flow will we be able to tackle new problems. At the moment, I am particularly interested in understanding the effect of transient winds.

Why is it important to model transient winds?

The majority of analyses undertaken to date, and hence the technical detail that our structural design codes are based upon, assumes that winds are stationary. This is based on the understanding that winds do not vary significantly over time. In reality most winds do have a transient component, but it is usually safe to ignore this since the transient nature occurs over a relatively long time period. Nevertheless, in some events, such as thunderstorm downbursts and tornados, this is not the case and significant changes can occur within a couple of minutes. For example, in 1983 in North America it took approximately three minutes for wind speed to increase from around 20 mph to 130 mph. There is limited full-scale data available on downbursts, however the data that have been collected highlight wind variability, so drawing conclusions is a challenging issue.

Could you describe how a vortex is created and why they are of particular interest?

As the downdraft (the name used for the wind before it hits the ground) is formed, there are essentially two fluids next to each other moving at different speeds. This creates what is called a shear layer. As a result of the 'two streams' of fluid moving at different speeds, flow tends to wrap up on itself causing a vortex. From observations in the laboratory, in the event of a downburst the vortex collapses as it interacts with the ground (initially impinging and then moving outwards) causing wind speeds to increase. However, as the collapsing vortex travels over the ground it will eventually dissipate as a result of surface drag (the friction arising from the ground).

Do you accurately model transient winds? What variables must be taken into account?

That is an interesting question since, given the limited full-scale data, no one really knows. However, we aim to simulate velocity time histories that look like and have the same statistical properties as those of available full-scale data. Given the run-to-run variability, accuracy is very important. We know the limits of the measuring equipment we use and stay within these parameters. In terms of control variables, we have varied the speed at which the downdraft travels, the height of the initial downdraft above the ground and the type of opening mechanism used to create the downdraft. The latter is paramount but the other two variables within certain limits are less important.

Is dissemination an important aspect of your investigations? How do you spread the word about your work?

Dissemination is vital to our work. We have published at a number of different conferences around the world. These include the 13th International Conference on Wind Engineering in The Netherlands, 2nd Latin American Conference on Wind Engineering in Argentina and last year's 8th Asia-Pacific Conference on Wind Engineering in India.

We now have plans underway to present our most up-to-date findings at the Wind Engineering Society conference being held at the University of Birmingham, UK, in September this year, and next year's 14th International Conference of Wind Engineering in Brazil. We have held dissemination events to the practising community at the Institution of Civil Engineers to engage with those interested in the work who do not generally attend conferences. In addition, I am very keen to see our message reach non-traditional audiences; for example, my team is working with a local primary school to undertake fun experiments for pupils aged eight and nine.

Studying the **breeze**

By reinterpreting traditional analysis methods and parameters in wind engineering, a team from the **University of Birmingham**, UK, is gaining new insights into the effect of strong transient winds on buildings, crops and people

GLOBAL WARMING IS bringing with it changes to the way storms track around the world and the levels of rainfall intensity. This is having an impact on the lives of many through damage resulting from very strong winds and intense rainfall episodes, as recently experienced in the UK during intense winter storms and flooding. The disruption from such meteorological events can be extensive, affecting properties and infrastructure and causing injury and loss of life, not to mention rapidly increasing financial implications, such as rising damage claims and resultant hikes in the cost of property and life insurance.

At the University of Birmingham's (UoB) School of Civil Engineering in the UK, a team of wind engineers is focusing on taking a very different approach to this growing global dilemma. Through their latest studies, the researchers are hoping to build a far more robust body of knowledge about the impact strong transient winds have on buildings, crops and people, which they expect will ultimately lead to improvements in building designs and better structural regulations.

DEVELOPING CONTEMPORARY TOOLS

The International Association for Wind Engineering defines wind engineering as the rational treatment of interactions between wind in the atmospheric boundary layer and man and his works on the surface of Earth. Essentially, the discipline explores the ways in which wind impacts the world and the damage that this can lead to. With major advances in understanding of the processes behind meteorological events, wind engineering is a rapidly evolving field.

In the past, the discipline has relied on traditional analytical tools to interpret data. But by taking a highly innovative research approach and building new methods and parameters, the UoB team – led by Professor Mark Sterling, Head of the School of Civil Engineering at UoB, with stong support from Dr Mike Jesson – has been able to simulate transient winds that correspond to what is likely to happen in the real world. Their work, which would not be possible without UK Engineering and Physical Sciences Research Council (EPSRC) funding, is a close collaborative effort with a number of scientists, including: Dr Ian Taylor from the University of Strathclyde, UK, who provides numerical modelling expertise; Professor John Schroeder from Texas Tech University, USA, an expert in full-scale data; and Professor Chris Lecthford from Rensselaer Polytechnic Institute, USA, who has extensive modelling expertise.

> One of the team's most valuable physical simulation tools is the University of Birmingham's transient wind simulator, which has the largest downward, vertical impinging jet in Europe

MAKING MODELS

The team's main means of investigating transient winds is to model extreme wind events, such as downbursts, through laboratory-based physical experiments and computational fluid dynamics (CFD) simulations which determine the force on structures. A significant challenge with studying such winds is that there is a limited amount of full-scale data available; due to the unpredicatable nature of transient winds, the cost of studying them in real time is prohibitive. Sterling explains that this is why most of their work is conducted using experimental models and tools in a laboratory setting: "The benefit of working at laboratory scale is that you can control a number of parameters and examine the effect of what happens if you change one small variable".

In order to physically simulate downbursts in the laboratory, two main approaches have been used – slot and impinging jets. One of the team's most valuable physical simulation tools is the UoB's transient wind simulator, which has the largest downward, vertical impinging jet in Europe. This simulator uses a 1 m diameter impinging jet with computer-controlled fans and aperture control flaps. The way the simulator is set up means they are able to generate a rapidly accelerating, transient flow field, which closely replicates the outflow and ring vortex of a full-scale downburst event. As a result, they have completed a wide range of simulations which are adding to understanding of thunderstorm downbursts effects: "Research performed using the simulator has so far examined interference effects and pressure

COLLABORATOR DR MIKE JESSON

INTELLIGENCE

DOWNBURST DYNAMICS AND THE IMPLICATIONS FOR ENGINEERING STRUCTURES

OBJECTIVES

To develop new insights into the effect of strong transient winds on buildings, crops and people.

PARTNERS

Dr Mike Jesson, University of Birmingham, UK

Dr Ian Taylor, University of Strathclyde, UK

Professor John Schroeder, Texas Tech University, USA

Professor Chris Lecthford, Rensselaer Polytechnic Institute, USA

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CONTACT

Professor Mark Sterling
Head, School of Civil Engineering

School of Civil Engineering
University of Birmingham
Edgbaston
Birmingham
B15 2TT
UK

T +44 121 414 5065
E m.sterling@bham.ac.uk

www.birmingham.ac.uk/schools/civil-engineering/people/profile.aspx?ReferenceId=8955

PROFESSOR MARK STERLING is Head of the School of Civil Engineering at the University of Birmingham. His research interests encompass fluid dynamics, wind engineering and water engineering. Currently, his focus lies in understanding the fundamental nature of wind flow and its effect on people, crops and buildings in order to develop novel approaches to solve structural challenges.

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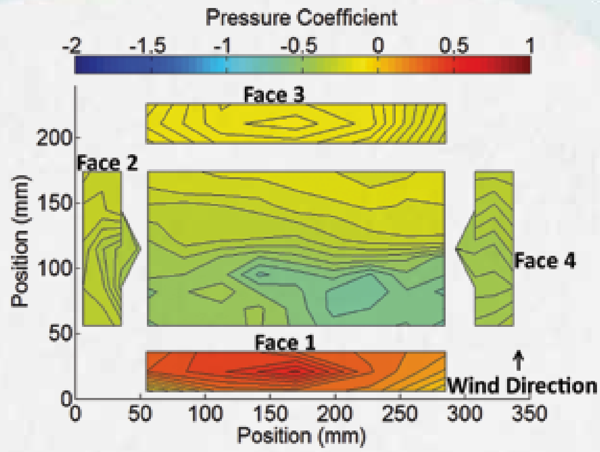

Pressure distribution over a portal-framed building at the moment the vortex strikes.

distributions on cubes and portal buildings," highlights Sterling.

Through such efforts, the international team has been able to simulate the pressure field impacting a high-rise building arising from downbursts: "We observed possible differences between such flow phenomena and those corresponding to typical boundary layer winds," explains Sterling. "However, the magnitude and importance of these differences currently remain open for debate." Much to the team's excitement, this work has produced significant new results. For example, the pressure distribution over cubes and portal-framed structures was examined at model scale in transient wind, which uncovered possible concerns: "This novel research has highlighted the difficulties in scaling and thus comparing results undertaken in other physical experiments which have examined the aerodynamic forces on structures in steady impinging jets," notes Sterling.

NUMERICAL SIMULATION

As computational power continues to increase rapidly, numerical models are proving to be evermore important in predicting the impact of downbursts. The numerical simulation component of the research is conducted at the University of Strathclyde, UK. CFD was initially used to help visualise what was happening around a physical model building. Two model buildings were used as case studies, each 3D printed with built-in pressure tappings. Although still in the early stages of this part of the investigation, numerical simulation has revolved around recreating what is known as the 'nose' of a downburst; where the maximum horizontal streamwise velocity is seen to occur close to the ground.

This year, the group is confident it will finish experiments examining the interaction of the downburst with these two different types of buildings: "This work will enable us to evaluate the wind-induced load on structures," remarks Sterling. "Also, we wish to understand the effect of surface roughness on vortex collapse."

CHALLENGES WITH SCALE

A major hurdle Sterling and his collaborators have come up against throughout their research is that experiments with identical parameters still result in a large amount of variation. "One approach to address this is to use physical simulations in conjunction with numerical simulations or computer models," Sterling asserts. "Physical simulations are ideal for calibrating numerical simulations, which in some cases can then be used to explore issues around scale." Sterling is enthusiastic about their early results, which already indicate good correlation between numerical and physical experiments. The team has also demonstrated that the current simulator is capable of creating field velocities similar to those observed in reality.

Ultimately, given the limited research undertaken in this area by other groups and the international collaborative effort that makes up the current project, Sterling is hopeful that his team's work will have significant impact on policy making and the development of structural design codes, as well as safer and more economical building design at local, national and global scales.