UCD Impact Case Study

Protecting the built environment from the effects of wind

Assistant Professor Jennifer Keenahan

UCD School of Civil Engineering

ACADEMIC · ECONOMIC · EDUCATIONAL · ENVIRON-MENTAL · SOCIAL · TECHNO-LOGICAL

SUMMARY

Hazardous wind conditions cause problems for everyone. While we can't stop the wind, we can design our built environment to mitigate its worst effects. Assistant Professor Keenahan is building and training a team to undertake wind modelling using Computational Fluid Dynamics (CFD), a method new to the field of Civil Engineering.

Her team is collaborating on projects with industry, who have recognised that CFD can be faster, cheaper, and more accurate than traditional methods. She is developing new policy for the treatment of wind in the built environment, resulting in improved infrastructure and a built environment that is safer and more comfortable for everyone.

"CFD presents a real opportunity to complement and enhance current practice and will aid our understanding of how structures behave under a myriad of wind loading conditions in a fast and cost-effective manner."

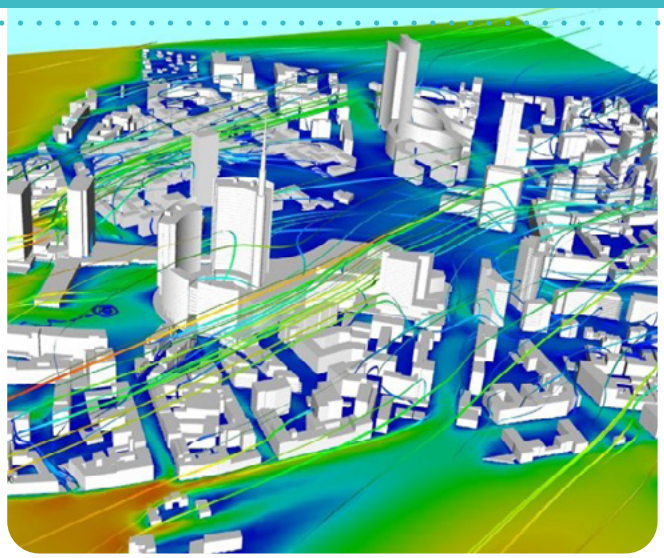
Fergal Cahill,
Transport Infrastructure Ireland

RESEARCH DESCRIPTION

Dr Keenahan studies how the wind can affect structures, pedestrians, and cyclists. High-sided vehicles (like lorries and buses) are vulnerable to overturning, structures may vibrate, and pedestrians and cyclists are at risk in exposed public spaces. Engineers, architects, planners, and designers are responsible for considering the effects of wind in their work.

Formed in 2017, Dr Keenahan's team is developing the use of Computational Fluid Dynamics (CFD) to model wind in the built environment. This approach aims complement, and potentially replace, traditional experimental wind tunnel testing. Wind tunnels present significant challenges in terms of accuracy, time and cost. CFD overcomes these challenges by modelling at full scale, with high resolution using parallel processing, saving time and money.

Validation – ensuring the models accurately represent wind in the real world – is key to the widespread use and adoption of CFD modelling. So far, this has been limited. To address this, Dr Keenahan is undertaking a mass-validation project, comparing CFD results to wind tunnel results and real-world data. Dr Keenahan's team began modelling a single vehicle, then an overturning crane, and onwards to a moving helicopter. With growing collaboration and capability, the team have now expanded to buildings, bridges, and even entire cities.



Visual results of wind in a cityscape generated using a CFD model.

Having fully validated CFD models enables decision-makers to investigate important safety, comfort, usability, and operational wind issues. Results demonstrate that CFD is an ideal tool for investigating wind effects. It can inform the early design stages, help to explore and compare different design options, offer high-resolution input for regulatory compliance, and analyse the wind environment in a fast, safe, efficient, high-quality, and inexpensive manner.

RESEARCH TEAM, COLLABORATORS AND FUNDING

Research team

- Assistant Professor Jennifer Keenahan (Team Lead).
- Yuxiang Zhang, PhD candidate at UCD.
- Licheng Zhu, PhD candidate at UCD.
- Gary Littler, Graduate Research Student, UCD.
- Assistant Professor Philip Cardiff, School of Mechanical Engineering, UCD.

Collaborators

- Matt Carter (Global Director of Arup Bridges), Marcos Sanchez, (Ireland Director of Bridges) and Reamonn MacReamoinn, (CFD Specialist) at Arup Dublin.
- Andrew Quinn, Reader in Atmospheric Science and Engineering at University of Birmingham.
- Fergal Cahill, Project Manager for Structures at Transport Infrastructure Ireland .
- Transport Scotland.

Funding

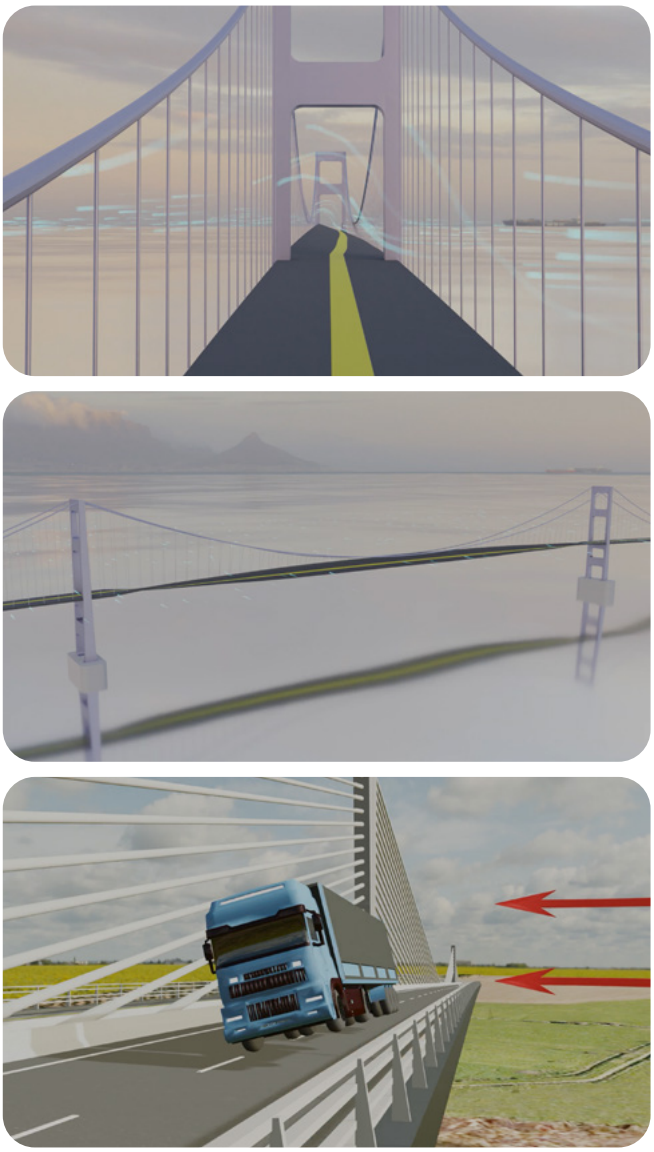
Three PhD students funded for 4 years by the Chinese Scholarship Council:

- 2018 – Wind Load Effects on Long-span Bridges using Computational Fluid Dynamics.
- 2019 – Assessment of Bridges for Wind Loading.
- 2020 – Water pollution control and energy conservation using Computational Fluid Dynamics modelling.

Research masters student funded by Geological Survey Ireland – Seabed Scour Assessment and Prediction Tools using CFD modelling.

Computing power was provided by the Irish Centre for High-End Computing (ICHEC).

Dr Keenahan and her team at Arup Dublin in 2018 presenting collaborative research.



Stills from animations showing the effects on wind on bridges and trucks.

"It is possible to gain a better insight into flow behaviours in the built environment using CFD. It is possible to explore the performance of solutions under a variety of conditions with the goal of producing more efficient and resilient designs."

Reamonn MacReamoinn, CFD Specialist, Arup

RESEARCH IMPACT

Economic impact

Dr Keenahan has been an invited speaker by Engineers Ireland and engineering and architecture firms in New York, Boston and Ireland. The number of Engineering Consultancy firms offering CFD modelling for the built environment as a service is ever increasing. An early adopter of this methodology, with whom Dr Keenahan works closely, now employs over 50 people on their CFD team with an annual turnover of €5 million, and have invested in dedicated servers to run CFD simulations. This represents a priority shift in expenditure. Every engineering firm that provides consultancy services in wind has the potential to benefit from a shift towards CFD.

Planning authorities are now accepting planning applications that include wind analysis using CFD modelling, some of which can be traced back to CFD work carried out by Dr Keenahan. Therefore, clients of the abovementioned firms will benefit from the reduced time and cost associated with CFD modelling as compared to wind tunnel testing.

Policy impact

Existing codes of practice for engineering – known as Eurocodes – give guidance on designing buildings to resist the forces of wind. But winds can have a significant impact on the comfort and safety of people and cyclists, and this is not yet considered in the codes of practice. Nor do the codes recognise CFD modelling. In the Irish context, only An Garda Síochána have the authority to close an area in what they perceive to be unsafe winds, without robust guidance on when to do so.

In conjunction with the National Standards Authority of Ireland, Dr Keenahan is preparing a policy on the holistic treatment of wind in the built environment. This will support decision-makers on the safe operation of infrastructure in high winds, and will include:

- Guidance on designing the built environment for safe and pleasant public use (e.g. occupant comfort on balconies).
- A protocol for preventing access to areas of the built environment due to dangerous wind conditions (e.g. closing a bridge).
- Guidance on using CFD modelling for wind analysis.

At the same time, Dr Keenahan sits on a working group revising the "Irish National Annex of the Wind Eurocode". All engineers across Europe must follow the Eurocodes, and each country can develop its own national annex for some country-specific issues. Dr Keenahan's research will therefore directly impact the next version of this code of practice for wind engineering, which is due to be published in 2022, with widespread adoption in 2025. The code is expected to include the use of CFD for preliminary wind analysis.

Social and environmental impact

Ultimately, Dr Keenahan's research will inform future design methods that will provide safer and more pleasant public spaces, better quality infrastructure, and safer transport in exposed wind environments. The research will benefit the whole of society by enhancing the user experience of the built environment.

What's more, faster wind speeds are highly likely to occur as a result of climate change, so this research is expected to become increasingly important and impactful in future years.

Academic, technological and educational impact

Using CFD to model the built environment represents the formation of a new discipline and is a step beyond the state-of-the-art. A special issue on this topic was proposed by Dr Keenahan in 2020 in the journal of Applied Sciences, where she is a guest editor. Dr Keenahan is building capacity through supervising four PhD students in the last three years. In this time, she has closely collaborated with Arup, through co-authoring publications, co-supervising six Masters of Engineering Research Projects, and the subsequent employment of one of these students in a specialist, highly skilled role on the CFD team at Arup.

"Wind actions on critical infrastructure, such as long span cable stayed bridges, and the response of such structures from both a structural and operational perspective are often the source of great debate and uncertainty during the detailed design and construction of large scale civil engineering projects. Wind loading parameters are often not adequately captured within design codes and numerous studies and wind tunnel tests are required in an attempt to establish realistic wind forces and their associated aerodynamic effects for a particular location and structure. Computational Fluid Dynamics presents a real opportunity to complement and enhance current practice and will aid our understanding of how structures behave under a myriad of wind loading conditions in a fast and cost-effective manner."

Fergal Cahill, Senior Engineer – Structures Engineering & Asset Management, Transport Infrastructure Ireland

REFERENCES

Video

Keenahan, J., (2020), Benefits of CFD modelling over Wind Tunnel Testing for Wind Analysis.

Special Issue

Special Issue on Computational Fluid Dynamics for the Built Environment in Applied Sciences.

Peer-reviewed academic publications

Bernardo, P., Réamoinn, R.M., Young, P., Brennan, D., Cardiff, P. and Keenahan, J., 2019. Investigation of the helicopter downwash effect on pedestrian comfort using CFD. *Infrastructure Asset Management*, pp.1-8.

Bernardo, P., MacRéamoinn, R., Cardiff, P., Keenahan, J. and Young, P. 2018. CFD Modelling of Helicopter Downwash and Assessment of its impact on Pedestrian Comfort. *Civil Engineering Research in Ireland Conference*, Dublin, Ireland.

Keenahan, J., MacReamoinn, R. and Paduano, C. (2017), Sustainable Design using Computational Fluid Dynamics in the Built Environment – A Case Study, *Journal of Sustainable Architecture and Civil Engineering*, 19 (2), 92-103.

Zhang. Y., Cardiff, P., and Keenahan, J., (2020) A Numerical Study of the Effect of Wind Barriers on Traffic and the Bridge Deck, *Proceedings of the Civil Engineering Research in Ireland Conference*, Cork.

Keenahan, J., Paduano, C. and MacRéamoinn, R., (2016), An overview of Arup Computational Fluid Dynamics Projects, *Proceedings of the Civil Engineering Research in Ireland Conference*, Galway.

Paduano, C., MacRéamoinn, R. and Keenahan, J., (2016), Design process to evaluate the potential of wind noise at façade elements, *Proceedings of the Civil Engineering Research in Ireland Conference*, Galway.

Zhang, Y., Cardiff, P. and Keenahan, J., (2020), A state of the art review of wind tunnel testing and CFD modelling of wind-induced phenomena in long-span cable-supported bridges, submitted to the Journal of Wind Engineering and Industrial Aerodynamics.

Newsletters

Arup (2018), Civil Engineering Research in Ireland Conference 2018, *Arup Ireland Technical News*, Oct 2018.

Arup (2016), Civil Engineering Research in Ireland Conference 2016, *Arup Ireland Technical News*.

Arup (2018), Collaborative Research into the built environment using CFD, *Arup Ireland Technical News*.

Companies offering CFD services

A sample of Engineering Consultancies offering services in CFD modelling for the built environment:

- RDWI
- Arup
- AECOM
- B-Fluid
- TESolution
- BRE Group

Invited speaker

Keenahan, J., MacReamoinn, R. and Paduano, C. (2016), Fluid Flows for the Built Environment, Presentation to Structures and Construction Division of Engineers Ireland, 5 December 2016.

Keenahan, J., (2016), *Fluid Flows for the Built Environment*, Presentation to Arup Cork, Ireland, 1 July 2016.

Keenahan, J., (2016), *Fluid Flows for the Built Environment*, Presentation to RKD Architects, Ireland, 20 June 2016.

Keenahan, J., (2016), *Fluid Flows for the Built Environment*, Presentation to Arup Boston, USA, 20 July 2016.

Keenahan, J., (2016), *Fluid Flows for the Built Environment*, Presentation to Arup New York, USA, 22 July 2016.

Awards

Won the Arup Malcolm Ryan award in 2016 for an entry entitled: '*An innovative approach to pedestrian wind comfort studies*' about using CFD over wind tunnel testing.

Dr Keenahan on a site visit to the Queensferry Crossing in Edinburgh.