The evolving landscape of CWE, from physical testing to computational methods and increasingly machine learning.

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In commercial practice, computational wind engineering (CWE) has been experiencing significant change over the last decade and that change only seems to be accelerating. Where the professional practice of wind engineering has been long dominated by physical testing, and for some applications computational fluid dynamics (CFD); artificial intelligence (AI) and in particular machine learning (ML) methods are starting to make their way into our respective practices and have meaningful impacts on how projects are designed and constructed. What does this mean for the ever-evolving wind engineer's toolbox? Is it a welcome addition or one fraught with risk? Is it both?

As we move through the AI/ML hype cycle, the landscape is starting to become clearer. These three technologies (Physical Tests, CFD and ML) are each valuable in their own way. The key for wind engineers will be to understand the ideal technology for any given application and for each, its associated limits. To that end, we need to understand the following:

1. How does each technology fit into the design cycle from both a technical accuracy and cost/time perspective,
2. How well these technologies perform in the various wind engineering disciplines, and
3. How standards bodies and regulatory authorities might accept these technologies.

With regards to the first point, we can think of the design process as three stages: early design (RIBA Stages 0-3), design refinement and optimization (RIBA Stages 2-3), and final design (RIBA Stage 4). Wind tunnels offer a robust approach to later stages, and in some cases are used earlier in the design process. CFD can stretch across all three stages with a vast array of available numerical approaches that may or may not be appropriate for a given discipline and representing a diversity of cost, time and precision. With the proliferation of CFD, the challenge is that not all actors in this space have the same view. I write "actors" and not strictly engineers because there are a growing number of technology providers and solutions in the market that are enabling non-expert practitioners to participate in the wind engineering services market, decoupling the expertise and understanding of the underlying physics from ability to operate a particular technological solver. ML shows great promise in accelerating early design by allowing low cost, iterative cycling but may further exaggerate challenges already experienced with CFD, and the challenge would be further complicated if ML approaches are imagined as part of the practice for later design stages.

As has been noted in various publications over the years, and based on the author's own experience, matching the approach to the discipline is crucial. For example, we have leveraged CFD quite successfully in all stages of pedestrian wind comfort, but we have yet to make significant inroads on some disciplines such as exhaust dispersion. On the other hand, very few wind tunnels are built for non-isothermal cases such as fire simulations. In these cases, CFD offers a viable pathway. Robust validation is also required and is missing in many cases, adding to confusion and mistrust. The same cycles of validation and confirmation will be even more important when we consider the potential of ML based approaches. With ML, the method and quality of data used to train the model is paramount, MLs trained with questionable CFD data will compound issues and amplify mistrust. This potential mistrust brings us to the third point, which is the role of standards bodies.

Standards bodies are by nature conservative and must provide generalized but reliable guidance for an incredibly diverse set of project applications. This means that there must be significant, compelling evidence that a new approach or technology provides a sufficient level of accuracy and reproducibility before being adopted. How the engineering community views these tools have a massive impact on the various standards. Indeed, engineers are often asked to write the standards. Again, deep understanding of the various approaches and their limitations is required, and this requirement for understanding increases as we move to ML based tools.

In this talk, the author will present on how CFD and ML fit into the design process along with some insights on how technologies used by the author were developed and validated. The various flavours of CFD and ML will also be discussed. The presentation will also touch on cost vs risk vs benefit in using the different technologies and provide insights on how these can be appropriately leveraged in the various disciplines such as microclimate, loading, cladding, air quality, wind driven rain etc.

The author will also provide some insight on the future potential for both CFD and ML technologies and how they provide a key pathway to tackling some of toughest challenges of our time, including applications that link to non-traditional metrics of societal importance such as reductions in embodied carbon in the AEC industry.