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On What New Building Project Managers Need to Know About Wind Engineering

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Abstract

The wind-engineering profession is becoming more commonly part of the design process and, also, as an advisor to builders during the construction phase. As project managers (PM) in both the design and construction phases are swamped by the many requirements of the building process it is easy for them miss the value of wind-engineering input at an early stage, or not even be aware of how the right advice can influence project attributes as varied as glazing choices, fatigue failures on roof appurtenances, pedestrian comfort and, even, the best location for an emergency generator. Having watched many young project managers make mistakes that wind-engineering advice could have avoided, and then seeing them move on in their careers to leave the next young PM to repeat the same errors, it seems prudent to outline some guidance that may form the basis of an institutional memory that avoids the repeated mistakes.

Introduction

The tertiary education of many young engineers, architects, and project managers is commonly very light on wind-engineering principals. The exposure to this field is often limited to some guest lectures followed by a discussion and cursory use of the relevant wind standard (AS/NZS1170, ASCE7, etc.). A full semester course in wind engineering at undergraduate level is now very rare. As a consequence the new, career-focused PM does not even know what questions to ask, and wind-engineering issues are simply not on his/her radar. Will the large fixed sunshades on a new façade resonate in common breezes, fatigue, and fall off? It has happened, but if the design team and builders have limited or no exposure to resonant dynamics and fatigue, the question will not even be asked. Will the tall rooftop porous screen generate an audible noise at modest wind speeds? Rarely a question even asked, until the owner complains in the first year of occupancy. How can buildings in a city canyon be designed to take advantage of natural ventilation? Does the architecturally stylish arcade penetrating the building at ground level (with, say, the main building access, coffee shops, and restaurants) connect the front and rear of the building for a dominant and strong wind direction? The architectural PM will not know to ask the question without the past lessons learned and recorded within the design studio; institutional memory (more common in the past) is now rarer as design professionals move from job to job and project to project.

A critical part of the process for better incorporation of wind engineering in projects and the enlightenment of PMs about the discipline is the education of wind engineers themselves, as well as their clients. Wind engineers need to be able to explain their discipline to others and to work well in integrated teams with multiple other disciplines. That requires transdisciplinary knowledge and skills on the part of wind engineers. These ideas are elucidated by Derickson et al (2008) and Derickson and Cochran (2013). The latter describes a new taxonomy of the discipline of wind engineering, the four domains in which it operates, the five pairs of vital objectives it serves, and various categories of application it addresses. Clients and PMs also can benefit from learning about the tools available to wind engineers in executing their craft, which include scale modeling in wind tunnels and computer simulations with computational fluid dynamics (CFD). Cochran and Derickson (2011) provide a review of the state of the art tools for wind engineering, elucidating their respective strengths and weaknesses.

Topics for the Design Team to Consider

- Is the structural engineer planning to use a code or standard like AS/NZS1170 or ASCE7 to estimate wind loads and cladding pressures, or is he/she anticipating a site-specific, building-specific a wind-tunnel study? What parameters are being used to make this decision? Architectural complexity is often an initial motivation, since the code tends to address more rectilinear designs. One does not have to be dealing with an architect like Gehry or Hadid to be confronted with unusual shapes. In the early years of wind engineering the building height may have been a parameter, but as the real cost of a wind-tunnel study has dropped dramatically such a study is no longer just the purview of tall buildings. It is more likely to be the building value that influences this decision. Recent input from building designers has suggested that the value of a wind-tunnel study for cladding pressures and structural loads may start to make sense at a project cost of 25 M$ or more. Architecturally complex, expensive, single-storey buildings are commonly examined with a physical wind-tunnel model. Dynamically sensitive structures can introduce another parameter of interest; upper floor accelerations. Achieving a small enough motion on the upper floors that the accelerations are imperceptible can be sufficient to engage a wind-engineering consultant. After all, an owner who buys a penthouse can also afford a quality lawyer!
- Is the building a laboratory or hospital with fume cupboard exhaust systems on the roof? Is there a heliport associated with the project? These features may be sources of noxious or odorous fumes that may be re-ingested into the HVAC system. Exploring these phenomena, and likely solutions, is far cheaper and effective at small scale in the wind tunnel than on the prototype building once the problem exists.
- Frequently buildings incorporate restaurants, laundries, and/ or small manufacturing facilities that generate noxious or odorous fumes. Misdirection of such odors to public areas by wind currents can reduce tenant satisfaction and the value of a completed building.
- If there is a roof-top heliport the ease of landing may be influenced by how the wind interacts with the nearby

structures or parts of structures. Some azimuths may be much more turbulent than others – a concern for pilots. Multiple hot-film profiles in the wind tunnel can easily quantify these effects to either modify the design or, at least, flag wind azimuths of potential concern to pilots.

- Are large external sunshades and/or porous screens planned for the outside of the building? Has consideration been given to a resonant response of these objects to the wind; producing fatigue failure or noise? The wind-engineering team can explore these façade appurtenances at full scale in a large wind tunnel (preferably one with anechoic characteristics) and help in any refinements needed to avoid problems with the finished product.
- Does the design have a spire or other lightweight attached element, exposed to largely undisturbed wind at roof level, which could respond dynamically via mechanisms like vortex shedding? Tall slender spires, with a uniform section, on the roof of a tall building may experience vortex shedding and a resonant response at such low wind speeds that it is a daily event (diurnal sea-breeze/land-breeze at height can be sufficient). To avoid fatigue of the spire attachments a damper or flow-modification device will be required. Discussion about design features like these early in the process can avoid anguish and value engineering deletions caused by fear (see Figure 1).
- Will roof mounted PV arrays be installed on the project? They are certainly becoming very common and will continue to do so (Lovins, 2011). If so, what design wind loads have been used to fix them to the roof? Who is responsible for this choice and analysis? Various codes and standards around the world give little or no useful guidance pertaining to wind loads for PVs. This is likely to change in future editions as many researchers and consultants have studied these (some for private clients) over a large range of variables: tilt angle, spacing, building height, parapet height, parapet porosity, elevator overrun proximity, location in the field, etc. However, at this point in time data from the wind tunnel, usually as part of a larger cladding study, is the best approach to obtaining differential wind loads for rooftop PV design.
- How will the roof parapet design affect possible movement of roofing ballast or pavers by wind? Displacement of roofing materials can cause significant damage to rooftop structures and nearby buildings.
- If the building contains internal atria, what actions have been taken to evaluate the effects of external winds on rooftop ventilators and building openings on the development of building fires and necessary evacuation plans?
- In cold climates the drifting of snow around the building base, into parking areas, around entrances and even on the roof around air handlers can result in physical and structural hazards. Often a wind-tunnel analysis can identify both problem areas and mitigation strategies in advance.
- Does the local council require any wind-oriented pedestrian comfort concerns to be addressed? Is an opinion letter sufficient, or is a wind-tunnel study required? Are long-term outdoor spaces like restaurants or pool decks part of the design? Are these recreation areas on the podium or between two towers? Will wind effect auto passenger access to the building or the safety of passengers transiting to a parking area? What is the orientation relative to the strong and common wind azimuths? If there are balconies, are they on the building corners or are they located at the middle of the building face? An experienced wind-engineering consultant can help the design team on topics like these, and many other considerations, if introduced to the project early enough in the architectural design process.
- If there are local authority requirements that pertain to wind issues, can an economic advantage be generated by addressing these requirements and adding some other economically advantageous tasks by commissioning a symbiotic wind-tunnel study? For example, if the local council requires that nearby pedestrian-wind conditions be addressed in the wind tunnel the cost of this work may be more than offset by exploring the cladding pressures on the new building, with likely savings, at the same time.
- Has the design team been approached to address wind issues using CFD/CWE technologies? If so, the engineer and architect need to be assured that the technology is being used correctly by a competent practitioner. Whether the end result is a hybrid merger of CWE and wind tunnel or pure CWE the output data may not be applicable for design (for a more in-depth discussion see Cochran and Derickson, 2011; Meroney and Derickson, 2014).
- Do wind loads on temporary structures during construction need to be considered?

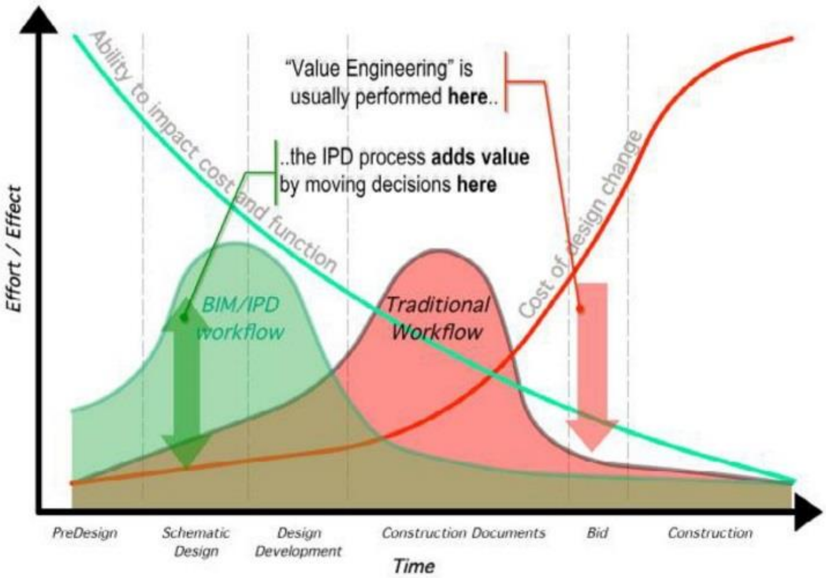

Figure 1: The well-known MacLeamy curve in which project management shifts efforts to the earlier project phases to achieve better quality through integrated project delivery (IPD). Earlier wind-engineering input may allow any ameliorative action needed to happen at little or no additional cost (after Derickson and Cochran, 2013).

Architectural PM

As the project leader, the architect will need to address thousands of design aspects. A small number of them will pertain to wind issues and, even though small in number, any one of them can result in a substantially diminished building for the owner if ignored. An entry or terrace that develops a reputation for being windy will reflect badly upon the whole design and, so, the architectural team in general. In this example the wind engineer must produce guidance and criteria suitable for the end use of the given locale (i.e. an outdoor restaurant must be calmer than, say, a building entry). That said, automated lobby doors that don't open on windy days, or in extreme cases fail, are very visible design problems that may be avoided by asking the right questions. Tall buildings that move too much in the wind become famous for the wrong reasons and lose tenants.

As building designers grapple with the green preferences of the owner and, more generally, society there may be a temptation to include concepts like natural ventilation, solar power, or architectural wind energy. The principal of ecologically sustainable design (ESD) is now considered conventional practice in Australia and some components require some wind-engineering input. For example, sunshades, screens, and awnings to reduce solar gain are common. Rain screen façade systems with internal voids, and the design goal of buildings with less façade leakage, are both building envelope design features that are not straightforward. Having a wind engineer on the team early will help with these topics and others such as dispersion of pollutants from sources like generators, kitchens and laboratories.

For example, large-scale wind energy devices on a tall building may have considerable appeal to the architect and owner – often for quite different reasons. It is a very effective way to announce environmental concern to the world and make the new project stand out. However, the handful of major buildings that have installed roof-top wind turbines have generally not been a success (Wilson, 2009). The power generated is routinely less than predicted with payback times greater than thirty years. Noise and fatigue failure are well documented. Discovery Tower in Houston is a classic example of the latter with two turbines failing and destroying two parked cars thirty storeys below. In many countries these devices are uninsurable and their wind rights are not well established as future proximate buildings appear.

Structural Engineering PM

The structural engineer is usually more focused on the technical and specific philosophical details of the design. For example, in the last decade or so tall buildings that are residential are more common. This used to be the purview of office buildings, but a condominium at 200 or 300 metres above the ground is less unusual now. As a consequence we are now seeing operable façades at substantial elevation. What does this do to the internal pressure assumptions for the structural engineer (internal partitions and even floor slabs) and the façade engineer? Can this be managed by building operations? Is there time to close all the windows prior to an extreme wind event – for a tropical cyclone, yes, but for a mid-latitude thunderstorm, probably no. Can technology help? One designer has installed a feature that does not allow the front door of the apartment be locked if any windows are open. One of many topics to discuss with the design team.

Another interesting consequence of tall buildings being residential rather that commercial is the trend of placing swimming pools at, or near, the roof. The lower fundamental frequency of these tall buildings has more chance of being coincident with the sloshing, or wave action, frequency of the swimming pool. The latter is obviously dependent on the pool shape and size, but there have been examples of pools losing about half their water during a major wind event, due to wave action. The wind engineer can work with the structural engineer and architect to ameliorate this possibility.

The structural engineer is most likely to lobby for the early engagement of a wind engineer – especially if he/she has experienced such collaboration (positively) in the past. That said, the focus is often on the dynamic structural wind loads, acceleration response and, perhaps, the cladding pressures. Topics like canopies, ancillary structures or appurtenances, spires, and shade structures (TFS or other materials) will often not be addressed in a timely manner without some prodding by the wind engineer.

Builder and Developer PM

The builder and developer may be one in the same, but as separate or joined players their priorities are usually quite different to the architectural design team. With costs as a prime driving force, and a plethora of young project managers determined to make their mark, the result can be wind-engineering errors repeated from one project to the next. Lessons are often not passed along with the changing PMs. Relationships are much more difficult to maintain in this transient environment than, say, with the structural engineer or the architect. As such, the wind engineer is often seen as a commodity rather than a trusted niche advisor. A proactive method of technology transfer and education (best done by the wind engineer) and institutional memory (best done by the builder or developer) is needed to avoid repeating the same wind-engineering problems. For example, some commonly repeated problems, in no particular order, include: ignoring environmental pedestrian-wind issues at entrances and plazas until the project is complete (sometimes when even warned by an earlier wind-tunnel study), not being aware of the effects of dynamics on smaller steel or aluminium structures like sunshades and rooftop features, not understanding the economic advantage of a site-specific, building-specific, wind-tunnel data for cladding pressures over the use of the code values, and leaving the decision to do such studies so late that the resulting data are of limited value.

From the developers' perspective the desire to embrace new and cutting-edge technologies can be guided by having the best advice. For example, the new lightweight façade systems that are now available are architecturally more complex and often contain a variety of materials; even quite innovative hi-tech materials as discussed by Cochran and Derickson (2013). Lacking an early interaction with an experienced wind engineer to assist with the composition of solid design criteria for the team, the developers are less inclined push into new technologies.

When the building PM is equipped with some knowledge and familiarity with wind-engineering principals they are more capable of directing the design in a more efficient direction, whilst still satisfying the client's functionality requirements. Without this skill set, or advice source, there will only be application of simple design criteria, with less original thought, that often yields overdesign and additional cost.

On Site Construction PM

It is less common for the personnel on site to seek input from the wind engineer, but it does happen on occasions. If there is an explosive demolition when the site is being cleared then advice on dust suppression and drift of the cloud may be sought. Temporary structures may be a source of wind engineering input, even if only a discussion of the appropriate return period to be used. Similarly, façade infill could be temporary in nature (at locations where the curtainwall may not be ready for installation) and require some discussion with site engineers and PMs. If there is a large or complex crane lift proposed (say, a large pre-manufactured roof component) then the wind engineer may be called to site to advise on the best time of day to avoid strong winds, for example.

Post Construction Wind Problems

Despite all due care during design and construction, often wind related faults may be found once tenants actually occupy the building. Situations exist where entrance doors have had to be locked to prevent entrance during dangerous building generated wind conditions, passengers have had to be escorted to cars across treacherous windy parking areas, suction pressures resulted in façade and window failure, and parapets required re-design to prevent ballast and pavers launching from roof tops. Such sick buildings have been repaired based on post-analysis using wind-tunnel and CFD analysis by wind engineers (Meroney et al., 2002).

Conclusions

Our relatively small field of wind engineering has matured from the niche areas of building/bridge wind loads, outdoor pedestrian comfort, and atmospheric dispersion to providing advice in almost all parts of the design process in the built environment. Consequently, the project managers at each step in the process need to be more aware of where our advice and services are useful to their goals. In the design studios of the architect and structural or mechanical engineer there are varying degrees of institutional memory that can certainly be improved. However, the builder, developer and, to a lesser extent, site PMs have a substantially higher turnover of personnel in their fields and almost no wind engineering knowledge or experience is passed on to the next PM. So, the new person is very likely to repeat the same, or similar, mistakes unless some proactive effort is made to record the lessons for others who follow within these organizations. We are living in an age of ample information with a very thin layer of knowledge or understanding. This is exacerbated by the transient nature of our modern professional histories – Millennial architects, engineers and PMs change companies more often than previous generations.

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