WIND ENGINEERING RESEARCH NEEDS

Wind storms are one of the greatest natural causes of damage and loss of man-made structures and material. They come in various forms but hurricanes, tornadoes and downbursts produced by thunderstorms, extra-tropical depressions and local topographically induced phenomena such as down-slope winds are the main types of wind to be considered. Major events like Hurricanes Andrew and Katrina cause loss of life, injury and tens of billions of dollars worth of damage in one single event. They are in the news for many weeks. Also, every year the local extreme winds caused by thunderstorms routinely cause death and destruction on a smaller scale but much more frequently. Although there have been significant advances in knowledge of the effects of wind on structures since the early 1960s, it is true to say that much of this has been gained on a shoestring budget. Funding for wind research has been tiny compared with that thrown into seismic-engineering research, despite the fact that in North America losses due to wind storms have historically far outweighed those due to earthquakes (Figure 1).

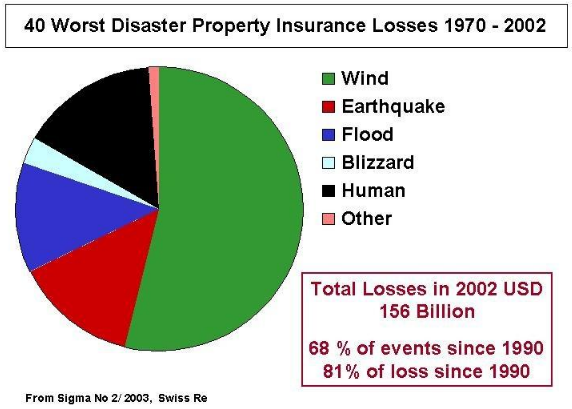

Figure 1: Insured losses from wind events are substantially larger than other causes.

Wind is also a very significant source of clean energy and wind farms are proliferating in many countries including the USA. The technology is developing rapidly not only in terms of the hardware but also in areas such as assessing the best sites, predicting and maximizing the power that can be obtained, dealing with environmental concerns such as noise, and tying the wind energy sources into the conventional power grids. In future the further development of effective wind power systems will require considerable research effort. Countries that have the most active research programs in wind power are most likely to become the leaders in providing equipment and services on a worldwide basis.

Much of the knowledge gained in the impact of wind on structures has come from project specific studies on large structures such as tall buildings, stadiums and arenas, and long span bridges. For these projects the research takes place in an ad hoc manner and the funding for this is absorbed within the design costs of each project. Often the wind engineering budget per project is in the $100,000 to $1,000,000 range. This “hidden” research funding, while allowing some advances to be made in small steps, does tend to be mostly of limited scope, because in the end the needs of the project must take precedence over any more lofty long term research goals. As a result the advances in general knowledge of the behavior of wind, wind statistics and wind loading of structures has been slow and sporadic. To make major advances a protracted and persistent research effort must be maintained over many years and have stable funding.

The vast majority of structures are not tall buildings, long span bridges, stadiums or arenas and do not receive the type of special attention the big projects receive. Funding for wind engineering research into this great majority of structures and the code wind provisions by which they are mostly designed has been pitifully small in the USA. As a result most structures are built using relatively crude information on wind loading, and this is because of the scarcity of research funding for this field. A similar situation exists for snow loading, which is closely linked to wind since most of the highest loading occurs in drifts caused by the interaction of snow with wind.

With the above as background the following subjects are seen as in great need of future research.

1. The wind loading of buildings is highly sensitive to shape. Very few shapes are handled in standards like ASCE-7. As a result designers are frequently uncertain how to interpret the standard for their particular building, because it does not look like any of the shapes for which load provisions are given. Added to this is the fact that the limited wind provisions that are given in ASCE-7 and other North American codes and standards are based on wind tunnel tests done over 30 years ago. Since then the technology of wind tunnel testing has advanced and can produce much more data, faster and with greater precision. Therefore, an extensive program of wind tunnel testing to establish design pressure coefficients for a wide range of different shapes is needed. One specific example has been suggested by the ASCE Committee on Special Structures: their Tensioned Fabric Structures Task Committee has pointed out the lack of any useful design, wind-load data in ASCE-7 for the dual-curvature smaller roofs (saddle and cone shapes) that form a huge part of that industry.
2. Wind loading is also sensitive to the surroundings of a building. Clearly the surroundings can be highly variable. Therefore, in parallel with item 1, research is needed into the uncertainties caused by this variability and the way that these can be accounted for in the code provisions for wind and the associated load factors. This topic needs a research team with expertise not only in wind loading and wind tunnel methodology but also in structural liability and risk. A test program with a range of potential surroundings is needed in order to establish realistic values of parameters like coefficient of variation that are used in structural reliability assessments. To establish appropriate levels of reliability achieved by code loads and load factors, Monte Carlo simulation methods should also be applied.
3. The analysis of extreme meteorological wind data has in the past mostly assumed that all wind data can be treated as part of a single population of events. In reality the events are due to several different types of phenomena such as outlined in the first paragraph. Research is needed into the consequences for design loads of analyzing the different types of wind storm as distinct populations. The vertical profiles of wind velocity and turbulence tend to differ in the different storm types and this could make current assumptions inaccurate for some types of structure.
4. In recent years substantial advances in meteorological modeling have been made, primarily as a result of developments in the field of weather forecasting. Research into how these techniques might be applied to improving the wind maps in North America could bring substantial benefits. Currently the wind maps are based on highly simplified analyses of ground based data obtained at airports. Regional differences tend to be lost in the scatter caused by local anomalies of the weather station and its surroundings. Advanced meteorological modeling tools can be used to detect true regional differences and eliminate scatter resulting from use of local ground based data alone.
5. The classification of exposure categories is still left much to the judgment of individual designers. They have to judge how rough the terrain is upwind of a site for each direction of importance, and they rely on simplistic descriptions given in code documents. With current GIS technology, satellite information and databases such as Google Earth it should be feasible to go to a web site, feed in your latitude and longitude and obtain on line a terrain roughness category or exposure coefficient as a function of height for any given wind direction. The development of this technology is feasible and would bring many benefits in improved consistency and accuracy. The choice of exposure category is one of the major sources of uncertainty in predicting wind loads from code provisions.
6. Wind tunnel tests on scale models are relied on heavily for determining wind loads on buildings, especially the larger structures. However, there are only a few rare cases where the real structure has been instrumented during or after construction so as to measure the wind loads and structural response. Information from such an instrumentation program provides invaluable guidance on the accuracy of

existing prediction methods and ways to improve them. In the absence of a good body of full scale data current prediction methods probably err on the conservative side, which causes additional construction cost and use of more resources than necessary. Billions of dollars can potentially be saved annually by in construction by spending a few tens of millions on structural monitoring programs focused on wind.

7. Similar to or in conjunction with (6) above, full scale building monitoring could also lend valuable information to structural engineers in developing structural models that better represent the actual building properties, including stiffness and the degree of cracking allowed for various return periods from serviceability to ultimate limit state.
8. Research needs to continue into the response of structures to tornado and thunderstorm downburst winds. This area of research is fairly new but methods of simulating these winds at small scale have been explored using specially designed wind tunnels and look promising. Tornados and thunderstorm downbursts are a significant cause of damage each year and ways of reducing this could pay big dividends. The impact of these winds on code requirements needs to be accounted for in a more rational way than is currently the case.
9. One area that has not received enough attention is the way that many ordinary low-rise structures actually respond to wind and snow loads. The detailed load paths and mechanisms of failure of many low rise structures built using traditional materials and methods are not well understood. Past research has shown that relatively small changes can have a dramatic impact on this type of structure's ability to withstand extreme loads. One example is the simple use of hurricane straps to secure the roofs of houses in hurricane areas. For the cost of a few dollars major improvements in safety are achieved.
10. The changing climate of the earth has the potential to alter the frequency and strengths of extreme wind and snow storms. Research into these effects is still at the rudimentary stages and this topic needs to be more vigorously pursued.
11. The snow load provisions in codes and standards are relatively primitive compared with the structural analysis software currently available to determine the effect of a given load. Thus, the potential benefits of the advanced structural software go to waste due to the low level of accuracy of the inputs. The heaviest snow loads are the drifting, i.e. through the interaction with wind. Therefore there are great potential benefits to be gained by developing improved knowledge of this interaction and through further developing methods for predicting extreme snow loads under different climate conditions.
12. The field of wind energy has a number of research needs. Methods for predicting the power available from a given site, taking into account the local terrain, do exist but need substantial improvement. Methods based on the full power of the latest Computational Fluid Mechanics and weather forecasting tools need to be explored. As well many aspects of wind turbine behavior are not fully understood, particularly their dynamic response to fluctuating wind loads, which if well researched could lead to substantially improved overall lifetime performance.
13. The installation of small turbines on buildings is becoming more popular but their performance in the complex air flows near a building is often disappointing due to lack of understanding of these airflows. Widespread use of such small installations is unlikely to take place until such problems are understood and solved.
14. The application of Computational Fluid Dynamics methods in wind engineering looks promising. It is already being used for a number of special applications such as flow over complex terrain, the comfort of pedestrians around buildings and wind loads on individual products such as satellite dishes. Continued development of these methods could lead to better understanding of many of the problems in wind engineering.

The tools and knowledgeable experts to do the above research exist but funding to put them to work has been missing. As a result the wind (and snow) provisions in even the most advanced standards such as ASCE-7 are not nearly as effective as they could be. The beneficial societal impact of the improved knowledge coming from such a program would be enormous, saving many lives and injuries and reducing by billions of dollars every year the cost of construction and the cost of damage from wind storms.

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