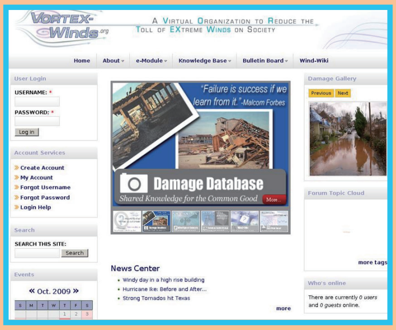
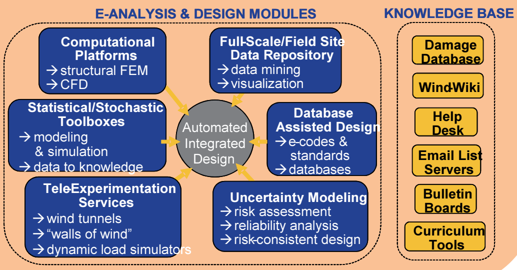
IG-WRDRR

Report of the International Group for Wind-Related Disaster Risk Reduction (WRDRR) in 2011





ISDR International Strategy for Disaster Reduction

GCOE Program TPU New Frontier of Education and Research in Wind Engineering

International Association for Wind Engineering

WDPC

International Group for Wind-Related Disaster Risk Reduction (IG-WRDRR)

The International Strategy for Disaster Reduction (ISDR) system partners are working together at global, regional and national levels to facilitate the implementation of the Hyogo Framework and increase political commitment and concrete actions on disaster risk reduction. Within the ISDR system, there are several thematic groups and platforms focusing on specific disaster risk reduction issues, such as disaster risk reduction and education, environment, capacity development, recovery, early warning etc. The International Group for Wind-Related Disaster Risk Reduction (**IG-WRDRR**) was established as one of these ISDR thematic groups during the Second Session of the Global Platform for Disaster Risk Reduction in Geneva, June 2009. Tokyo Polytechnic University and IAWE are the leading organizations of this ISDR thematic group on wind-related disaster risk reduction.

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Report of the International Group for Wind-related Disaster Risk Reduction (WRDRR) 2011

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The International Group (IG) for Wind-Related Disaster Risk Reduction (WRDRR) was formally launched under the auspices of the United Nations / International Strategy for Disaster Reduction Secretariat (UN/ISDR) at the Global Platform (GP) for Disaster Risk Reduction (DRR) held in Geneva, Switzerland, from June 16-19, 2009. This Group is responsible for establishing linkages and coordinating various communities to serve as inter-agency coordinators with a charter to work with international organizations involving agencies of the UN and involved NGOs, and to embolden their activities that help to serve as a bridge between policy makers and agencies responsible for actually carrying out the DRR at the local community level. This report consists of five sections. Sections 1.0 and 2.0 introduce briefly the necessity and recent activities of IG-WRDRR. Sections 3.0 and 4.0 illustrate the Saffir-Simpson Scale and Enhanced Fujita (EF) Scale that are used to describe the intensity of hurricanes and tornados. Finally, Section 5.0 introduces an engineering Virtual Organization for Reducing Toll of EXtreme Winds on Society (VORTEX-Winds).

1.0 Introduction of IG-WRDRR

Wind-related disasters such as Cyclone Nargis in Myanmar in 2008 and Cyclone Sidr in Bangladesh in 2007 have had significant impacts on our society, especially in terms of the shocking numbers of deaths and injuries to people and the attendant property loss. It has been reported that the majority of natural disaster economic losses in the world are caused by extreme wind related events, and it is hypothesized that global warming has the potential to further exacerbate this scenario through an increase in the number and intensity of weather-related disasters. On the other hand, devastating hazards, e.g., tropical cyclones, are generally accompanied by high waves, storm surge, heavy rains, floods, landslides and lightning. This calls for concerted efforts in pooling of expertise and cooperative actions to reduce losses from various types of natural disasters. Despite recognition of this critical need for cooperative actions in WRDRR activities among various professional organizations, there has been no notable collaborative effort among the various groups in the past. During the symposium of Cooperative Actions for Disaster Risk Reduction (CADRR) co-hosted by International Association for Wind Engineering (IAWE), UNU (United Nation University), UN/ISDR, ADRC (Asia Disaster Reduction Center) and the TPU (Tokyo Polytechnic University) Global COE Program, the representatives from IAWE, the International Association for Earthquake Engineering (IAEE), UN/ISDR, ADRC, the World Meteorological Organization (WMO), the National Oceanic and Atmospheric Administration (NOAA) and others reached a consensus that there is a critical need to establish an international group to work on WRDRR. Consequently, IG-WRDRR was formerly established during the Second Session of the GP for DRR organized by the UN/ISDR Secretariat in 2009. IG-WRDRR is responsible for establishing linkages and to coordinate various communities to serve as inter-agency coordinators with a charter to work with international organizations involving agencies of the UN and involved NGOs, and to empower them with the responsibility to serve as a bridge between policy makers and agencies responsible for actually carrying out the DRR at the local community level.

All the efforts of IG-WRDRR are directly related to the implementation of the Hyogo Framework for Action in the area of wind-related disaster risk reduction. The main expected activities of IG-WRDRR include:

- to implement the Hyogo Framework for Action in the area of wind-related disaster risk reduction;
- to establish a database/warehouse of the latest information/technologies relevant to wind-related effects and their mitigation;
- to facilitate technology transfer that attends to the needs of local communities exposed to disasters around the world;
- to provide assistance to international organizations in the preparation of guidelines to manage the impact of wind-related disasters including evacuation, recovery and reconstruction;
- to organize, dispatch and facilitate ground logistics for quick-response post-disaster investigation

teams;
- to establish an international consensus for extreme winds based on damage relevant to different construction practices;
- to establish international guidelines to prepare for wind-related disaster reduction activities;
- to harmonize wind-loading codes and standards including environmental specifications;
- to facilitate development of a global Engineering Virtual Organization (EVO) for WRDRR; and
- to hold regular international workshops/conferences on WR DRR.

Discussion on the work of IG-WRDRR can be carried out through the existing platforms established by IAWE, including VORTEX-Winds and APEC Wind Engineering Network anytime, or at APEC-WW every year, or at ICWE and Regional CWEs every four years. Organized post-disaster investigation activities can be coordinated through these platforms to avoid overlapping disaster investigations and excessive rescue supply, which often become a burden for local communities amidst a disaster. In addition, education and transfer of advanced wind hazard mitigation technologies to developing typhoon/cyclone-prone countries can be carried out through these platforms. The output of this group will be reported at UN/ISDR GP for DRR in Geneva every two years.

2.0 Recent initiated activities of IG-WRDRR

1) The International Forum on Tornado Disaster Risk Reduction for Bangladesh

"The International Forum on Tornado Disaster Risk Reduction for Bangladesh - To Cope With Neglected Severe Disasters" in Dhaka, Bangladesh, on 13-14 December, 2009 was co-organized by the Tokyo Polytechnic University Global COE Program (TPU-GCOE), the Government of Bangladesh (Disaster Management Bureau, Ministry of Food and Disaster Management, Meteorological Department, Ministry of Defence), the Bangladesh Disaster Preparedness Centre (BDPC) and the International Association for Wind Engineering (IAWE) as the first official event of IG-WRDRR. As one of the outcomes of this forum, ten recommendations were made to help the Government of Bangladesh to adopt policies and carry out development planning to reduce risks from severe local storms (SLS) and to stimulate donor agencies and NGOs to implement specific projects to reduce SLS disaster risks. The report of the Forum including Position Paper, Recommendations etc. is available from http://www.iawe.org/WRDRR/documents/BangladeshFinalReport.pdf.

As a follow-up of the International Forum, IG-WRDRR held a mini-workshop on Tornado Shelter for Bangladesh on January 25-26, 2011 in Dhaka with the cooperation of BDPC and SEEDS Asia. Due to the complex mixture of storms experienced in Bangladesh and the structurally weak housing found in rural villages, the devastation a storm causes demands that more attention be paid to rescuing and caring for victims than to documenting exactly what happened meteorologically. Hence, there has arisen a need to understand the meteorological phenomena of tornadoes and to determine how villages can prepare themselves to avoid devastation. The IG Chairman, one of the authors, described the basic characteristics of typical tornados and possible indicators to assess tornados as well as their damage patterns. Discussions involving community members and scientists regarding construction of household tornado shelters were made, resulting in a possible diagram to prepare a shelter house at minimum cost.

The International Forum on Tornado Disaster Risk Reduction for Bangladesh, Bangladesh

2) APEC-WW & IG-WRDRR Joint Workshop and 4AMCDRR Pre-Conference Event

IG-WRDRR was involved in organizing "IG-WRDRR & APEC-WW Joint Workshop on Wind-Related Disaster Risk Reduction Activities and Inter-organizational Collaborations" and "Climate Change and Wind-Related Disaster Risk Reduction Activities in Asia-Pacific Region" in Incheon, Korea, in October 2010. The latter was a Pre-conference event of the 4th Asian Ministerial Conference on Disaster Risk Reduction.

The purpose of these workshops was to share the current status and activities for WRDRR in the Asia-Pacific region. It was found that member economies of APEC-WW (Regional Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies) have different wind climates and different levels of extreme/strong wind risks. All member economies engaged in some forms of WRDRR activities with varying degrees of support and participation at national, state/provincial and district levels, including wind damage assessment, wind-related disaster reduction activities and natural disaster mitigation strategy. It was also found that various WRDRR activities received varying degrees of acceptance by the general population and achieved varying degrees of success. Overall, APEC-WW & IG-WRDRR Joint Workshop and 4AMCDRR Pre-Conference Event provided a good platform for mutual exchange of information and knowledge between wind engineering experts, people working on DRR in various organizations, and policy makers.

Discussions were held on the fact that even though science and technology have been significantly developed, the number of natural disasters and damage are increasing. It was realized that it is necessary to consider the minimization of the risk of future wind-related disasters, which continue to escalate with population shifts towards urban centers located in the paths of typhoons/cyclones and the impending threat of their increased intensity and frequency as hypothesized by potential climate change. In addition, people agreed that severe local wind storm disaster risk reduction continues to be very challenging because it is difficult to forecast and give warning without advanced detecting systems. To cope with these identified main challenges or constraints, it is considered necessary for IG-WRDRR to support the development of user-friendly local guidelines on wind-resistant design for developers/ constructors, and the importance of better assessment of climate change impacts on the frequency and intensity of wind-related hazards at the country level was identified.

3) Brochures on Preparedness for Wind-Related Hazards in Haiti

The Haiti Earthquake occurred on January 12, 2010, and caused severe damage to the Port-au-Prince area and fatalities numbered almost 200,000. Haiti is located in a strong hurricane-prone region, and it faced a hurricane season following the severe earthquake damage, which made it more vulnerable to wind hazards. Thus, IG-WRDRR prepared brochures in English and French in March, 2010, to warn Haitians about the possibility of coming wind related hazards as well as to provide them with basic guidelines for mitigation.

The brochure recommended that local people and authorities have a "Preparedness Plan" for wind-related disaster prevention and reduction. These brochures were distributed to Haitians, central and local governments of Haiti, UN organizations and other supporting and donor agencies in various ways. They were also available through UN/ISDR PreventionWeb (http://www.preventionweb.net/english/), IAWE website (http://www.iawe.org/) and others.

Brochures on Preparedness for Wind-Related Hazards in Haiti (English version and French version)

4) International Symposium on Wind Effects on Buildings and Urban Environment

Recently, the number of severe wind incidents that caused loss of life, serious societal impact and threats to national as well as regional security has been increasing. The effects of rapid urbanization, global warming and climate change are now regarded as indirect causes of these disasters. Rapid urbanization and population concentration from burgeoning economic development in Pacific-rim countries have increased energy consumption and worsened air quality as well as thermal comfort in urban environments. In order to tackle these problems, it is essential to reduce energy consumption by utilizing building ventilation and also to reduce air pollution as well as heat pollution by actively promoting urban ventilation. The primary purpose of this symposium, which was co-organized by TPU-GCOE and IG-WRDRR, is to provide an ideal venue for exchanging and sharing information through discussion, so that serious wind-related problems regarding wind hazard risk due to meteorological turbulence such as typhoons and tornadoes, urban air pollution and increase of environmental load can be solved. The forum aims at contributing to the development and construction of sustainable urban environments with low energy built environments and hence to achieve wind hazard resilient cities.

5) Other activities

In order to prompt cooperation with other international organizations and to contribute globally to WRDRR, the IG Chairman, one of the authors, participated in the following cooperative activities for disaster risk reduction: The 6th Meeting of the Asia Regional Task Force on Urban Risk Reduction (UN/ISDR) in Kobe on January 14, 2010; The 4th APEC Emergency Management CEOs' Forum (UNCRD, MOFA Japan) and the International Disaster Management Symposium - Urban and Climate Risk Management for Sustainable Development 2010 in Kobe on January 18-20, 2010; Asian Conference on Disaster Reduction 2010 (SAARC: South Asian Association for Regional Cooperation) in Kobe on January 17-19, 2010; Typhoon Committee (UNESCAP & WMO) in Singapore on January 25-29, 2010.

3.0 The Saffir-Simpson Hurricane Wind Scale

The Saffir-Simpson Hurricane Wind Scale is a 1 to 5 categorization based on the hurricane's intensity at the indicated time. The scale – originally developed by wind engineer Herb Saffir and meteorologist Bob Simpson – has been an excellent tool for alerting the public about the possible impacts of various intensity hurricanes (Saffir 1973, Simpson 1974). Engineers and scientists have used it extensively to characterize the peak wind speed conditions and the associated damage states of the affected building stock.

The scale provides examples of the type of damage and impacts in the United States associated with winds of the indicated intensity. In general, damage rises by about a factor of four for every category increase (Pielke et al. 2008). The maximum sustained surface wind speed (peak 1-minute wind at the standard meteorological observation height of 10 m [33 ft] over unobstructed exposure) associated with the tropical cyclone is the determining factor in the scale. (Note that sustained winds can be stronger in hilly or mountainous terrain – such as the over the Appalachians or over much of Puerto Rico - compared with that experienced over flat terrain (Miller and Davenport 1998). The historical examples provided in each of the categories correspond with the observed or estimated maximum wind speeds from the hurricane experienced at the location indicated. These do not necessarily correspond with the peak intensity reached by the system during its lifetime. It is also important to note that peak 1-minute winds in hurricane are believed to diminish by one category within a short distance, perhaps a kilometer [~ half a mile] of the coastline, because of the increase in surface roughness from marine to overland fetch. The reduction in wind speed is further enhances by changes in the storms' structure and intensity as it supply of moisture and heat is cut off. For example, Hurricane Wilma made landfall in 2005 in southwest Florida as a Category 3 hurricane. Even though this hurricane only took four hours to traverse the peninsula, the winds experienced by most Miami-Dade, Broward, and Palm Beach County communities were Category 1 to Category 2 conditions. However, exceptions to this generalization are certainly possible.

The scale does not address the potential for other hurricane-related impacts, such as storm surge, rainfall-induced floods, and tornadoes. It should also be noted that these wind-caused damage general descriptions are to some degree dependent upon the local building codes in effect at the time of construction and how well and how long they have been enforced. For example, building codes enacted during the 2000s in Florida, North Carolina and South Carolina are likely to reduce the damage to newer structures from that described below. However, for a long time to come, the majority of the building stock in existence on the coast will not have been built to higher code. Approximately 80% of single-family homes in hurricane prone-areas were constructed before 1994 (US Census Bureau). Hurricane wind damage is also very dependent upon other factors, such as duration of high winds, change of wind direction, quality of construction (craftsmanship), and age of structures.

Earlier versions of this scale – known as the Saffir-Simpson Hurricane Scale – incorporated central pressure and storm surge as components of the categories. The central pressure was used during the 1970s and 1980s as a proxy for the winds because accurate wind speed intensity measurements from aircraft reconnaissance were not routinely available for hurricanes until 1990 (Sheets 1990). Storm surge was also quantified by category in the earliest published versions of the scale dating back to 1972 (OFCM 1972). However, hurricane size (extent of hurricane-force winds), local bathymetry (depth of near-shore waters), topography, the hurricane's forward speed and angle to the coast also affect the surge that is produced (Jelesnianski 1972, Irish et al. 2008). For example, the very large Hurricane Ike (with hurricane force winds extending as much as 200 km [~125 mi] from the center) in 2008 made landfall in Texas as a Category 2 hurricane and had peak storm surge values of about 20 ft. In contrast, compact Hurricane Charley (with hurricane force winds extending at most 25 mi from the center) struck Florida in 2004 as a Category 4 hurricane and produced a peak storm surge of only about 7 ft. These storm surge values were substantially outside of the ranges suggested in the original scale. Thus to help reduce public confusion about the impacts associated with the various hurricane categories as well as to provide a more scientifically defensible scale, the storm surge ranges, flooding impact and central pressure statements are being removed from the scale and only peak winds are employed in this revised version – the Saffir-Simpson Hurricane Wind Scale. The impact statements below were derived from recommendations graciously provided by experts (Bruce Harper, Forrest Masters, Mark Powell, Tim Marshall, Tim Reinhold, and Peter Vickery) in hurricane boundary layer winds and hurricane wind engineering fields (Masters et al. 2009, Marshall 2009).

Category One Hurricane (Sustained winds 74-95 mph, 64-82 kt, or 119-153 km/hr).
Very dangerous winds will produce some damage.
People, livestock, and pets struck by flying or falling debris could be injured or killed. Older (mainly pre-1994 construction) mobile homes could be destroyed, especially if they are not anchored properly as they tend to shift or roll off their foundations. Newer mobile homes that are anchored properly can sustain damage involving the removal of shingle or metal roof coverings, and loss of vinyl siding, as well as damage to carports, sunrooms, or lanais. Some poorly constructed frame homes can experience major damage, involving loss of the roof covering and damage to gable ends as well as the removal of porch coverings and awnings. Unprotected windows may break if struck by flying debris. Masonry chimneys can be toppled. Well-constructed frame homes could have damage to roof shingles, vinyl siding, soffit panels, and gutters. Failure of aluminum, screened-in, swimming pool enclosures can occur. Some apartment building and shopping center roof coverings could be partially removed. Industrial buildings can lose roofing and siding especially from windward corners, rakes, and eaves. Failures to overhead doors and unprotected windows will be common. Windows in high-rise buildings can be broken by flying debris. Falling and broken glass will pose a significant danger even after the storm. There will be occasional damage to commercial signage, fences, and canopies. Large branches of trees will snap and shallow rooted trees can be toppled. Extensive damage to power lines and poles will likely result in power outages that could last a few to several days. Hurricane Dolly (2008) is an example of a hurricane that brought Category 1 winds and impacts to South Padre Island, Texas.

Category Two Hurricane (Sustained winds 96-110 mph, 83-95 kt, or 154-177 km/hr).
Extremely dangerous winds will cause extensive damage
There is a substantial risk of injury or death to people, livestock, and pets due to flying and falling debris. Older (mainly pre-1994 construction) mobile homes have a very high chance of being destroyed and the flying debris generated can shred nearby mobile homes. Newer mobile homes can also be destroyed. Poorly constructed frame homes have a high chance of having their roof structures removed especially if they are not anchored properly. Unprotected windows will have a high probability of being broken by flying debris. Well-constructed frame homes could sustain major roof and siding damage. Failure of aluminum, screened-in, swimming pool enclosures will be common. There will be a substantial percentage of roof and siding damage to apartment buildings and industrial buildings. Unreinforced masonry walls can collapse. Windows in high-rise buildings can be broken by flying debris. Falling and broken glass will pose a significant danger even after the storm. Commercial signage, fences, and canopies will be damaged and often destroyed. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks. Potable water could become scarce as filtration systems begin to fail. Hurricane Frances (2004) is an example of a hurricane that brought Category 2 winds and impacts to coastal portions of Port St. Lucie, Florida with Category 1 conditions experienced elsewhere in the city.

Category Three Hurricane (Sustained winds 111-130 mph, 96-113 kt, or 178-209 km/hr).
Devastating damage will occur
There is a high risk of injury or death to people, livestock, and pets due to flying and falling debris. Nearly all older (pre-1994) mobile homes will be destroyed. Most newer mobile homes will sustain severe damage with potential for complete roof failure and wall collapse. Poorly constructed frame homes can be destroyed by the removal of the roof and exterior walls. Unprotected windows will be broken by flying debris. Well-built frame homes can experience major damage involving the removal of roof decking and gable ends. There will be a high percentage of roof covering and siding damage to apartment buildings and industrial buildings. Isolated structural damage to wood or steel framing can occur. Complete failure of older metal buildings is possible, and older unreinforced masonry buildings can collapse. Numerous windows will be blown out of high-rise buildings resulting in falling glass, which will pose a threat for days to weeks after the storm. Most commercial signage, fences, and canopies will

be destroyed. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to a few weeks after the storm passes. Hurricane Ivan (2004) is an example of a hurricane that brought Category 3 winds and impacts to coastal portions of Gulf Shores, Alabama with Category 2 conditions experienced elsewhere in this city.

Category Four Hurricane (Sustained winds 131-155 mph, 114-135 kt, or 210-249 km/hr).
Catastrophic damage will occur
There is a very high risk of injury or death to people, livestock, and pets due to flying and falling debris. Nearly all older (pre-1994) mobile homes will be destroyed. A high percentage of newer mobile homes also will be destroyed. Poorly constructed homes can sustain complete collapse of all walls as well as the loss of the roof structure. Well-built homes also can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Extensive damage to roof coverings, windows, and doors will occur. Large amounts of windborne debris will be lofted into the air. Windborne debris damage will break most unprotected windows and penetrate some protected windows. There will be a high percentage of structural damage to the top floors of apartment buildings. Steel frames in older industrial buildings can collapse. There will be a high percentage of collapse to older unreinforced masonry buildings. Most windows will be blown out of high-rise buildings resulting in falling glass, which will pose a threat for days to weeks after the storm. Nearly all commercial signage, fences, and canopies will be destroyed. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Long-term water shortages will increase human suffering. Most of the area will be uninhabitable for weeks or months. Hurricane Charley (2004) is an example of a hurricane that brought Category 4 winds and impacts to coastal portions of Punta Gorda, Florida with Category 3 conditions experienced elsewhere in the city.

Category Five Hurricane (Sustained winds greater than 155 mph, greater than 135 kt, or greater than 249 km/hr).
Catastrophic damage will occur
People, livestock, and pets are at very high risk of injury or death from flying or falling debris, even if indoors in mobile homes or framed homes. Almost complete destruction of all mobile homes will occur, regardless of age or construction. A high percentage of frame homes will be destroyed, with total roof failure and wall collapse. Extensive damage to roof covers, windows, and doors will occur. Large amounts of windborne debris will be lofted into the air. Windborne debris damage will occur to nearly all unprotected windows and many protected windows. Significant damage to wood roof commercial buildings will occur due to loss of roof sheathing. Complete collapse of many older metal buildings can occur. Most unreinforced masonry walls will fail which can lead to the collapse of the buildings. A high percentage of industrial buildings and low-rise apartment buildings will be destroyed. Nearly all windows will be blown out of high-rise buildings resulting in falling glass, which will pose a threat for days to weeks after the storm. Nearly all commercial signage, fences, and canopies will be destroyed. Nearly all trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Long-term water shortages will increase human suffering. Most of the area will be uninhabitable for weeks or months. Hurricane Andrew (1992) is an example of a hurricane that brought Category 5 winds and impacts to coastal portions of Cutler Ridge, Florida with Category 4 conditions experienced elsewhere in south Miami-Dade County.

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4.0 Development of Enhanced Fujita (EF) Scale for Intensity of Tornadoes

Tornadoes are the most severe wind storms in nature. They are spawned out of thunderstorms and occur randomly lasting relatively for a short time. Tornadoes are rotating column of air (a vortex) with wind speed as high as 320 kmph. Because of the randomness of occurrence of storm and short life of the storm, it has not been possible to measure wind speeds in tornadoes. Additionally, if one of the tornadoes passes over a wind speed measuring instrument, an anemometer, it is likely to get destroyed due to high winds. Hence, intensity of tornadic storm is assessed indirectly through assessment of damage to buildings and structures.

Dr. Thedore T. Fujita at the University of Chicago developed the Fujita Scale (F-scale) to assess the intensity of tornadoes in 1971 (Fujita, 1971). He wrote an equation for wind speed between Beaufort 12 and Mach 1 and divided it in twelve parts, F1 to F12. This division provided wind speed ranges for each F-scale. Using his own judgment, he put each type of damage that can occur in each F-scale, F1 through F5. The F-scale worked well when it was developed as it permitted the categorization of tornadoes by their intensity and the level of damage and destruction they caused. However, there were several deficiencies in the F-scale.

The primary limitations in F-scale were a lack of damage indicators, no account of construction quality and variability, and no definitive correlation between damage and wind speed. United States National Weather Service (USNWS) personnel, who are responsible for rating tornadoes, expressed frustrations in applying the Fujita Scale in a consistent and accurate manner. Weak links in a structural system or a slow-moving storm can sometimes lead to an over-rating of a tornado event. Several technical articles in engineering journals suggest that the wind speeds associated with some descriptions of damage are too high. For example, a 420 kmph wind speed is not required to completely destroy a well constructed house and blow away the debris: the damage occurs at significantly lower wind speeds. A major drawback in Fujita Scale is that damage intensities are arbitrarily assigned to F-scale categories.

A vast amount of damage data in tornado events has been collected since the inception of F-scale in 1971. These data can be used to better define wind speeds that can cause the damage. Enhanced Fujita (EF) Scale is a paradigm shift from the F-scale; in original F-scale wind speed ranges were defined by an equation and damage levels were arbitrarily considered. In the new EF-scale, wind speeds are judged based on damage and EF-scale category is assigned based on wind speed.

To assess wind speed based on damage, different types of buildings and constructions are considered; these are called Damage Indicators (DIs). In addition, a Degree of Damage (DOD) for each DI is judged for assessing wind speed. This process of assigning wind speed for each DI and each DOD is based on the expert judgment of several specialists and is called the elicitation procedure.

Based on the damage documentation archive of the Wind Science and Engineering Research Center at Texas Tech University (between 1970 and 2010 more than 100 tornado event damages are archived), 26 DIs are identified varying from single family residences constructed with wood to warehouse metal buildings to reinforced concrete government buildings. These 26 DIs cover most of the buildings and construction materials in the United States. Each of the DIs has 6 to 10 DODs, and thus there are more than 200 different damage levels for the assessment of wind speed.

The elicitation procedure involved six damage investigator specialists, three wind engineers and three meteorologists. They were provided with photographs of different DIs and varying level of DODs. The specialists assigned wind speeds to each DI and DOD. After obtaining averages of wind speeds for each DI and DOD, the specialists were allowed to change their wind speed values. This iteration process is the elicitation procedure. Details of DIs, DODs and elicitation procedure are given in the Enhanced Fujita Scale report submitted to US NWS (EF-scale, 2006). The US NWS implemented use of EF-scale in February 2007 and since that date all tornadoes are rated as EF0 to EF5 category.

The procedure for assigning an EF-scale category is as follows:

- Identify 8 to 10 DIs in the center of the path of a tornado damage
- Judge the DOD for each of the identified DI
- Assign wind speed to each DI/DOD
- Discard the top and bottom wind speed values as outliers
- Take an average of the wind speed value and assign EF-scale category using the tabulated value shown below.

The new EF-scale is based on engineering judgment of the level of damage. In addition, it provides more flexibility in assigning EF-scale category to a tornado as well as the results will be more consistent. Until we develop remote sensing instrument that can measure wind speed in a tornado, intensity of a tornado can be judged by assigning EF-scale category.

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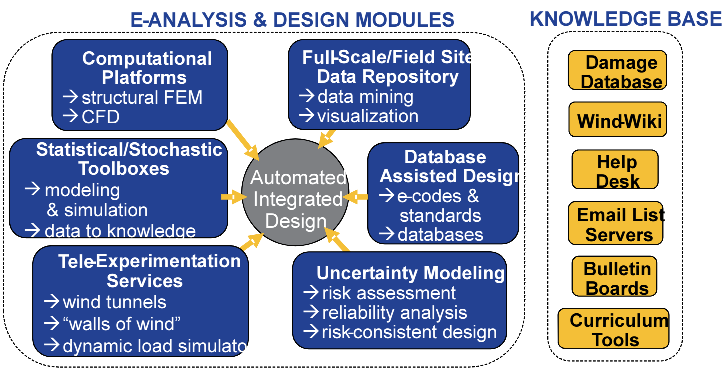
5.0 Development of Engineering Virtual Organization for Reducing Toll of EXtreme Winds on Society (VORTEX-Winds)

VORTEX-WINDs -- Virtual Organization to Reduce the Toll of Extreme Winds on Society is being developed at Notre Dame in collaboration with the Global Center of excellence at the Tokyo Polytechnic University and a host of founding members. VORTEX-Winds would serve as an end-to-end system that integrates domestic and international community resources related to wind effects on structures. It would facilitate an effective and conveniently accessible venue for the acceleration of advances in research and development, as well as teaching and learning, in this area and would have a revolutionary impact on this field due to its unprecedented dissemination of knowledge and re-sources.

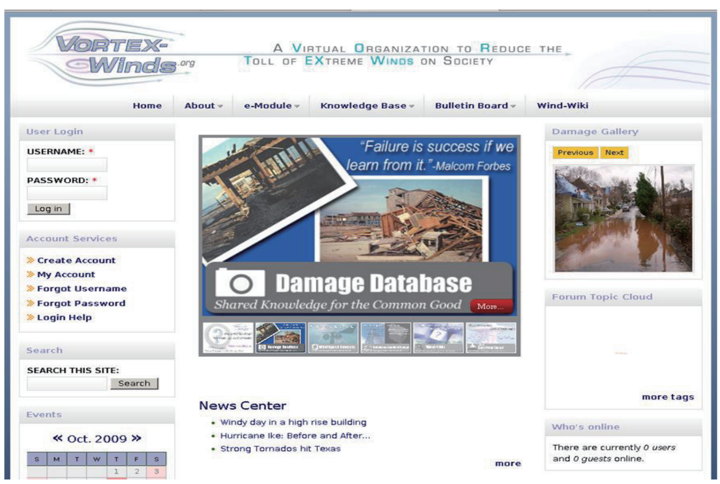
The objectives of this project are:

- To establish VORTEX-Winds – Virtual Organization to Reduce the Toll of Extreme Winds on Society (VORTEX-Winds coordinates geographically dispersed e-analysis and design modules and knowledge base to enable automated, integrated analysis and design of structure and facilitates education and training of future work force.
- To establish and sustain a community contributing to and employing the resources integrated by cyberinfrastructure technologies.
- To enhance analysis and design capabilities concerning the effects of extreme winds on civil infrastructure.
- To facilitate education and training of the future work force in the field.

An overall structure of the collaboratory organization is divided between two sections and is shown below:



An overview of the current portal of VORTEX-Winds is presented below which can be found at www.vortex-winds.org



Currently this project has

- Established initial membership of the virtual collaboratory that includes participation from global members and organizational structure of the collaboratory.
- Developed basic architecture of the e-analysis and design modules and knowledge base.
- Developed a Drupal-based secure web portal to serve as the collaboratory cyber-interface.
- Developed a database assisted design module for high-rise by integrating databases at Notre Dame and Tamkang University (a member of the collaboratory).
- Currently two database assisted design modules for low-rise structures are in preparation involving databases from NIST and TPU.
- Commenced the population of the knowledge base, e.g., windwiki, crowd sourcing of the analysis of glass damage in Hurricane Ike and comprehensive damage database.
- Developed background material for merging stochastic simulation of wind related processes from the NatHaz NETECH portal and simulation platform from our collaborators from the University of Genoa.
- Developed preliminary framework for tele-experimentation module for remote web-enabled operation of experiment in NatHaz bench-top multi-fan wind tunnel.

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International Group for
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