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In This Issue

International Association for Wind Engineering

Tuscaloosa and Joplin Tornadoes: Preliminary Observations

Bill Coulbourne, Applied Technology Council
Director of Wind and Flood Hazard Mitigation
bcoulbourne@atcouncil.org

Figure 1:
Exterior wall collapsed – no connection at footing

Figure 2:
Puddle welded connection on top of wall failed

A team, consisting of university engineers and scientists as well as industry professionals, surveyed the structural damage caused by both the April 27th tornado which ripped through the city of Tuscaloosa, AL, and then the May 22nd tornado which devastated Joplin, MO. The tornadoes cut approximately a ½ - 1 mile wide swath through the centers of both Tuscaloosa and Joplin. Much of the residential construction consisted mainly of older 1930s to 1970s buildings and light commercial structures, with some newer multi-family structures scattered throughout. These were powerful tornadoes that the National Weather Service (NWS) rated as an EF4 in Tuscaloosa and an EF5 in Joplin. Approximately 5000 buildings were lost and 500 businesses were lost or directly affected by the tornado in Tuscaloosa. In Joplin, over 8000 buildings were destroyed or damaged and over 150 people lost their lives. Over a period of 1.5 weeks at the two locations the team looked at hundreds of homes and other structures. Preliminary observations of the structural damage and some generalized mitigation approaches to save lives and reduce losses are discussed below.

Many of the failures of the older buildings can be attributed to the lack of continuous vertical and/or lateral load paths, not just too excessive wind speeds. In a series of perpendicular transects to the tornado's path, the team observed a gradual reduction in severity of damage from the center of the path towards the edges. While there was complete destruction and some houses shifted completely off their foundations at the center of the path, between 100 to 200 yards further away, major structural components (some roof trusses, walls) failed but the building remained in place, and beyond 200 yards from the center, houses had severe siding damage, loss of roof covering, broken windows and failed patio/porch roofs. Many of the buildings at the outer boundaries of the damage swath had a discontinuity in vertical load paths created by inadequate connections at critical locations. This is not a surprising finding given the age and the location of these buildings in a non-hurricane area where no building code mandates special attention to the details of load paths

The study team found numerous examples in load path failures where detailing in compliance with current building codes for hurricane-prone regions would have reduced the damage and potentially reduced injuries. Unfortunately, some of these discoveries were in school buildings, two built within the last 10 years. These examples included a lack of physical attachment of precast-concrete walls to footings or to adjacent wall panels (Figure 1), insufficient attachment and no redundancy in the support of metal bar joist roof framing systems into load bearing walls, and the lack of adequate lateral support at the top of exterior walls (Figure 2). The team also observed frequent failures in masonry infill walls where there was no or minimal reinforcement. The designs of these buildings in several cases appeared to rely primarily on gravity to keep the vertical support systems intact. There was no evidence in any of the schools or other "engineered buildings" that safe rooms had been considered as a possible life saving design technique. It is important to point out that these buildings were designed to the minimal wind speeds of 90 mph. Drawings were not available. So there is no information about the consideration of an Importance Factor in the wind design pressures.

For less-intense tornadoes (EF0-EF2), it may be possible to save lives and reduce injuries if, in those areas with a history of strong tornadic activity, load path enhancement techniques known to work in hurricane-prone regions of the country were added to local construction practices. At the moment, these enhancement techniques would be optional for owners since they are not required by the building code, but the techniques would need to be fully understood by builders and building code officials so that for those who want them, the quality of the construction and inspections insures improved building performance when the building is impacted by a tornado.

The team strongly believes that as structural engineers we should not accept the fact that people need to risk perishing in their homes or their schools from a tornado because the wind speeds are too high and thus there is nothing we can do. There appears to be significant evidence that at the lower tornado wind speeds associated with EF0-EF2 there are known construction practices and techniques that could be used to enhance the typical construction used in the lower design wind speed areas in the center of the country. One developed solution for protection of the occupants already practiced in "tornado alley" is the installation of safe rooms. For whatever reason though, this life-saving practice is not yet widely used. The team believes that other building strengthening practices for these types of events should be developed and then demonstrated by local builders and building officials as being accepted into local building practices for those building owners or users who want to reduce their risk of injury or death from tornadoes.

The damage inspection team members were:
Dr. David O. Prevatt (Univ. of Florida), Leader; Dr. John van de Lindt (Univ. of Alabama), Dr. Rakesh Gupta (Oregon State Univ.), Dr. Andrew Graettinger (Univ. of Alabama), Dr. Shiling Pei (South Dakota State Univ.), Sam Hensen, P.E. and Bryan Wert, P.E. (Simpson Strong-Tie), Bill Coulbourne, P.E. (Applied Technology Council), Thang Dao (Univ. of Alabama), Dr. David Grau (Univ. of Alabama), John Miller, P.E. and Ben Jennings, P.E. (J&M Engineering – Springfield, MO) and graduate and undergraduate civil engineering students from the University of Florida, University of Alabama, Iowa State University and Clemson University.

FEMA Mitigation Assessment Team (MAT) Investigates Tornado Damage

Tom Smith, AIA, TL Smith Consulting

tlsmith@hughes.net

The Federal Emergency Management Agency (FEMA) deployed a Mitigation Assessment Team (MAT) to investigate buildings damaged during the April tornado outbreak. Investigations occurred in AL, MS, TN, and GA. Another MAT was deployed in investigate the damage that occurred in late May at Joplin, MO.

The team's goals were: (1) investigate and assess the performance of safe rooms and shelters, and document damages observed; (2) investigate and assess residential building performance, focusing on newer construction where possible; (3) evaluate the performance of large commercial facilities that were directly impacted; (4) investigate and assess the performance of critical and essential facilities (e.g., hospitals, schools, emergency operation centers, fire stations, communication towers, etc.); (5) evaluate operational issues resulting from damage of critical facilities (e.g., the effect of damage on response and recovery); and (6) evaluate and provide field evidence to determine the tornado ratings on the EF Scale for the evaluated locations.

The MAT consists of FEMA personnel and contractor subject matter experts. The members are represented by architects, engineers, and meteorologists. After returning from the field investigations, the MAT developed six new Recovery Advisories (RAs) are now available for download from the FEMA Library: http://www.fema.gov/library/viewRecord.do?id=4723

- RA1 – Tornado Risks and Hazards in the Southeastern United States
- RA2 – Safe Rooms: Selecting Design Criteria
- RA3 – Residential Sheltering: In-Residence and Stand-Alone Safe Rooms
- RA4 – Safe Rooms and Refuge Areas in the Home
- RA5 – Critical Facilities Located in Tornado-Prone Regions: Recommendations for Facility Owners.
- RA6 – Critical Facilities Located in Tornado-Prone Regions: Recommendations for Architects and Engineers.

In the aftermath of the May 3, 1990 Oklahoma and Kansas tornados (FEMA 342), over ten years ago FEMA published landmark design and construction guidance for residential safe rooms (FEMA 320) and community safe rooms (FEMA 361). A significant outcome of the recent MAT investigations pertains to the development of guidance for critical and essential facilities. Recovery Advisories RA5 and RA6 provide recommendations to minimize building damage during weak and strong tornadoes. These RAs also provide recommendations to avoid interrupted operations for those facilities where continued operations are vital even if struck by a violent tornado (EF4 or EF5).

The MAT is preparing a comprehensive report that will be available around the end of the year.

Figure 1: This ten year old one story school had three classroom wings and a central core area. One classroom wing and most of the central corecollapsed. This is a view of the central core area.

Figure 2: Tree fall caused severe building damage.

Figure 3: Most of the second floor of one wing collapsed at this 14-year-old school. It had a steel frame with CMU/brick veneer exterior walls.

Figure 4: General view of a new housing complex.

Figure 5: At this unit all of the walls were blown away.

Figure 6: The roof structure blew away at this unit. Interior bathrooms such as this one often provide safe refuge during weak or strong tornadoes. However, a 2x4 and other wind-borne debris entered this bathroom. This illustrates the importance of having a safe room as recommended in FEMA 320. http://www.fema.gov/library/viewRecord.do?id=1536

Tornadoes in April 2011

Carol Friedland, Louisiana State University
friedland@lsu.edu

Stuart M. Adams, LSU
Elizabeth Chisolm, LSU

Project Overview

Following the historic tornadic events of April 27th, 2011, a team of Louisiana State University (LSU) researchers conducted damage assessments in Alabama and Mississippi on May 6th and 7th. The team was deployed by LSU's new Condition Assessment and Prediction using Technology to enhance oUtreach, Research and Education (CAPTURE) Lab and was led by Department of Construction Management Assistant Professor Carol Friedland, PE, PhD. The team also included PhD students Stuart Adams, Elizabeth Chisolm, and Vipin Unnikrishnan.

The major objectives of the reconnaissance project were the training of students in damage assessment techniques and capturing damage to critical community facilities, such as police stations, fire stations, schools, government buildings and key commercial facilities. The primary tools used for capturing damage were damage assessment forms, photography, and geo-referenced high-definition video using the VIEWS™ System developed by ImageCat, Inc. of Long Beach, California.

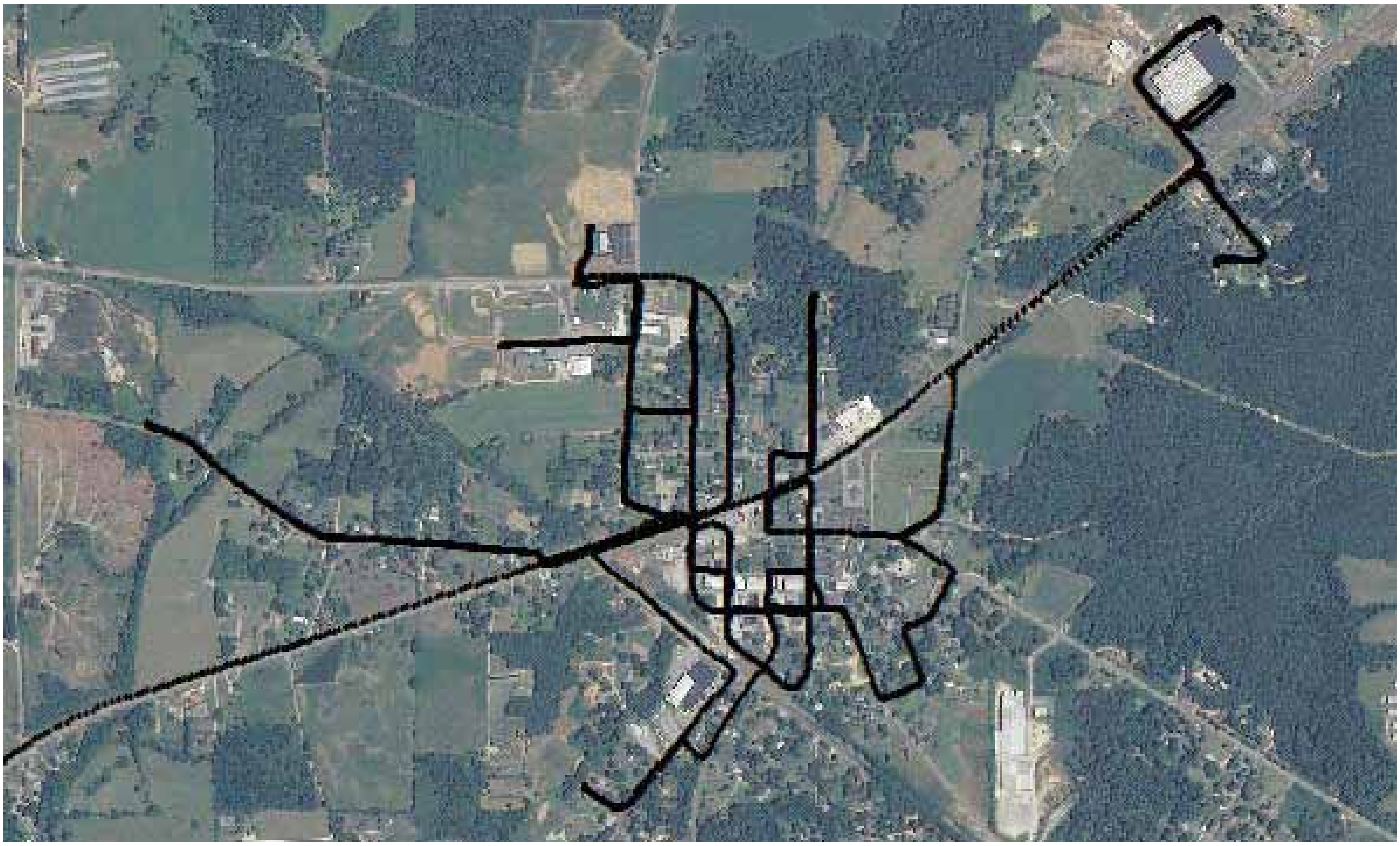
Deployment & Assessment Plan

The deployment plan included three main locations: Tuscaloosa, AL, Hackleburg, AL, and Smithville, MS. The team completed assessments on May 6th in Tuscaloosa and Hackleburg. On May 7th, further assessments were completed in Hackleburg and Smithville. In Tuscaloosa, the team focused on hands-on training of students regarding damage assessment techniques, including compiling data on survey damage forms and classifying tornado damage using procedures outlined in the Enhanced Fujita Scale. In Hackleburg and Smithville, the team assessed critical community structures and captured geo-referenced video of both towns. Damage Indicators (DIs) and Degrees of Damage (DODs) for over 15 structures were completed during the deployment.

Figure 1: LSU PhD students assessing tornado-damaged residences, Tuscaloosa, AL

Tuscaloosa, AL

The team collected detailed damage data for two homes in Tuscaloosa (Figure 1) as part of the training phase of the deployment. The team also met with Dr. David Prevatt from the University of Florida, Dr. Rakesh Gupta from Oregon State University, Dr. Shiling Pei from South Dakota State University and Mr. Bill Coulbourne from the Applied Technology Council to discuss the damage assessments conducted in Tuscaloosa, Alabama.



Hackleburg, AL

In Hackleburg detailed damage assessments were completed on 13 critical community facilities: including the police station, fire station, post office, townhall/recreation center, the Wrangler distribution facility, a communication building, five school structures and two churches. In addition to the assessments, the team also captured high-definition geo-referenced video of the town (Figure 2). In the downtown area, the majority of buildings were older masonry one and two-story buildings that experienced moderate damage, including damage to roofs and masonry walls. The downtown area included the police station, fire station, post office, town hall/recreation center and communication building. Of these structures, the police station sustained the highest level of damage and appeared to be the oldest of the four structures (Figure 3). The post office and communication building suffered little or no damage. The majority of school buildings were unreinforced, concrete masonry with brick veneer. Most of the school buildings suffered moderate to severe damage, including failure of roofs, and partial collapse of interior and exterior masonry walls (Figure 4). Of the two church buildings assessed, one was an older predominantly masonry structure and the other a newer metal building. Both were in the vicinity of the school buildings and both suffered moderate to severe damage. The worst damage was observed at the Wrangler Distribution facility, which was a metal framed structure with tilt-up concrete panel exterior walls. This facility was completely collapsed. Overall, it was interesting to note that the damage in Hackleburg appeared to be more widespread than the other communities that were assessed with no clear line of distinction between mostly-damaged and mostly-intact structures.

Figure 2: GIS trail of VIEWS data, Hackleburg, AL

Figure 3: Police Station, Hackleburg, AL

Figure 4: School Buildings, Hackleburg, AL

Figure 5: GIS trail of VIEWS data, Smithville, MS

Smithville, MS

In Smithville the team completed detailed assessments on the post office, police station and town hall and captured high-definition geo-referenced video of the town (Figure 5). Both the police station and town hall were completely collapsed, and only a small portion of the post office, containing the bathrooms and electrical room, was left standing. A detailed assessment was not completed on the Smithville school structures but it was observed that the buildings sustained roof damage throughout. Also, one large residential area experienced severe damage, with the majority of buildings suffering complete destruction. The team was fortunate to speak with Gregg Kennedy, the current mayor of Smithville. Mayor Kennedy gave his personal recount of the event and spoke of sheltering under a conference table as the building surrounding him was destroyed. Approximately two-thirds of the community was severely damaged by the tornado that passed through Smithville, MS on April 27.

Figure 6: Post Office, Smithville, MS

Future Project Work

Analysis of geo-referenced video collected using the VIEWSTM System is currently in progress. Completion of this task should help to further confirm the EF rating of the Hackleburg and Smithville tornadoes. Additionally, the need for more efficient means to collect enriched data following such events was cited. LSU's CAPTURE Lab intends to address this need through tablet computer applications and Unmanned Aerial Vehicle (UAV) platforms. These devices offer many advantages over current data collection practices and are sure to become an integral part of future CAPTURE Lab deployments.

Announcement of the Alan G. Davenport Wind Loading Chain

On July 12, 2011 during ICWE-13 in Amsterdam, the General Assembly of the International Association of Wind Engineering (IAWE) unanimously approved the use of the term the "Alan G. Davenport Wind Loading Chain" for describing Alan Davenport's approach for evaluating wind loads and wind-induced responses for buildings and structures. Many of us remember Alan G. Davenport's name in connection with a number of specific technical aspects of wind engineering. These include his power law wind profiles; his spectrum of turbulence; his admittance and joint acceptance functions, which describe the spatial and temporal properties of turbulence as required in the evaluation of dynamic wind action; his gust effect factor; his pioneering use of wind tunnel model studies to chart the dynamic properties of buildings and structures; his statistical methods for predicting maximum values of extreme winds and their effects of wind on buildings and structures; and his criteria for judging the effects of wind on building occupants and pedestrians. Notwithstanding his influence on these and many other specific aspects of wind engineering, his greatest legacy is his rational approach or "chain of thought", which ties together these various concepts in the development of the methodology for evaluating the action of wind particular buildings and structures.

Professor Davenport's approach or chain of thought is described as follows:

Alan's approach recognizes that the wind loading on a particular building or structure is determined by the combined effects of the local wind climate, which must be described in statistical terms; the local wind exposure, which is determined by the terrain roughness and topography; the aerodynamic characteristics of the building shape; and the potential for load increases due to possible wind-induced resonant vibrations. He also recognized that clear criteria must be in place for judging the acceptability of the predicted loads and responses. These include the effects of wind on the integrity of the structural system and the exterior envelope and various serviceability considerations which influence performance and which determine habitability. The latter include the wind-induced drift, the effects of wind-induced motion on occupants and the usability of outdoor areas of the project, as well as its immediate surroundings.

In his papers Alan referred to this process for evaluating wind action as the wind loading chain. This was in recognition that the evaluation of wind loading and its effects relies on several interconnected considerations, each of which requires scrutiny and careful assessment. With analogy to a physical chain, the weakest link or component of the process determines the final outcome. Little is gained by embellishing strong links but much is lost by not paying attention to the weak ones.

Alan and others have written about this wind loading chain and have used this chain concept to describe and solve specific wind engineering problems. Perhaps the most lucid raison d'être for this "chain" was articulated by Alan himself in his Chapter 12 of the book entitled "Engineering Meteorology", edited by Eric Plate and published by Elsevier Scientific Publishing Company in 1982. This chain or multiplicative process for arriving at wind loads has been adopted in many building codes and standards. Not only is it effective for formulating the loads and responses to wind action, it is also a powerful model for evaluating the reliability of the final outcome. For example, the coefficient of variation of the predicted wind action to a good degree of approximation is equal to the square root of the sums of the squares of the coefficients of variation of each of the individual links. In the case of wind loads, the coefficient of variation (CV) can be approximated as follows

$$CV_{wind\,load} \approx (CV^2_{reference\ wind\ pressure} + CV^2_{wind\ exposure} + CV^2_{aerodynamic\ shape} + CV^2_{dynamic\ action})^{1/2}$$

It is most fitting that the IAWE has decided to posthumously honor the late Alan G. Davenport by adding the "Alan G. Davenport Wind Loading Chain" to the wind engineering terminology. This is done in recognition of Alan's many contributions to the development of wind engineering. It is hoped that the usage of the term "Alan G. Davenport Wind Loading Chain" to describe the wind loading process, as Alan developed it, will keep both the man and his work in our memory.

Nicholas Isyumov

Consulting Director
Boundary Layer Wind Tunnel Laboratory
The University of Western Ontario
London, Ontario, Canada

The proposal submitted to the IAWE to formally recognize the term "Alan G. Davenport Wind Loading Chain" for use by the wind engineering community was supported by the following colleagues at the BLWTL:

Horia Hangan, Director
Eric Ho, Director
Peter King, Director
Greg Kopp, Director
David Surry, Consulting Director
Barry Vickery, Consulting Director

Call For Papers Due September 9, 2011

Call for Papers

We invite you to join us in building an exciting program by submitting abstracts for individual presentations and proposals for complete sessions. The conference will include both oral and poster presentations. Novel session formats, such as panel discussions and debates, are encouraged. Proposals should focus on topics consistent with the list published below . **All proposals are due September 9, 2011.**

How to Submit a Proposal

For additional instructions on how to upload an abstract or session proposal to the paper management system please visit the **conference website**. Submissions will be reviewed by the Conference Program Committee for decisions on acceptance. All presenters of accepted proposals are strongly encouraged to submit 10-12 page final papers for inclusion in the conference proceedings. All proposals should be sufficient to judge the quality and appropriateness of the work for the conference.

Suggested Topics

Review the list of topics below as you prepare your submission. A complete list of topics and subtopics can be found on the **conference website.**

- Wind Engineering - General
- Coastal Flooding
- Engineering for the Building Envelope
- Low Rise Buildings - Wind
- High Rise Buildings - Wind
- Infrastructure - Wind and Flood
- Meteorology and Oceanography
- Risk Modeling and Forensic Engineering - Wind and Flood

Dates to Remember

Save the Conference date: October 24-26, 2012
Call for Papers Due: September 9, 2011
Notice of Acceptance: January 5, 2012
All Final Publication Ready Papers Due: April 25, 2012

Visit the conference website for all the up to date information.

Contact Debbie Smith, Manager, SEI Programs if you have questions dsmith@asce.org or 703-295-6095
Joint Conference Organized by the Applied Technology Council and the Structural Engineering Institute
http://www.atc-sei.org/

President's Corner

I certainly hope you had a wonderful and productive summer. In our previous newsletter, I mentioned about the active tornado season in the US and ensuing damage that occurred this year. The current newsletter brings to you several articles from the members of the tornado damage survey teams based on their observations and findings. This year has seen incredible with five tornadoes of EF-5 rating. Despite a 24-minute tornado warning lead-time, the EF-5 tornado that ploughed Joplin, Missouri on May 22, 2011 claimed 141 lives. It has become the 7th deadliest tornado in U.S. history and 27th-deadliest in world history (Wikipedia). I was personally involved in the tornado damage survey at Joplin. One of the buildings that I was able to access was the Joplin High School that was severely damaged. We assume that the probability of a building hit by an intense tornado is pretty low. Guess what? Since 1971 Joplin was hit by a tornado three times of which Joplin High School building was hit twice.

One of the main highlights for this summer other than an active tornado season was the 13th International Conference on Wind Engineering (ICWE) at Amsterdam, Netherlands from July 10-15. It was a very well attended conference with 500 plus attendees including a significant number of participants from the Americas region. I was glad to see several student-participation from this region that were partially funded and made possible through AAWE and IAWE (International Association for Wind Engineering) travel grants. The AAWE Board had its first meeting under my term on July 14th during the conference. The attendees had a very invigorating discussion on several aspects of AAWE business. You will be able to view the minutes of this meeting through the AAWE Web site in near future. Among other events, IAWE had a general assembly meeting on July 12 in which member organizations that include AAWE voted through its representatives or delegates on key issues of IAWE. Out of the three proposals that were submitted to host the next international conference (14th ICWE), two from North America and one from South America, the proposal from the Brazilian Wind Engineering Society (which is a new addition to the Americas Region) was selected with a clear majority. Thus, the next ICWE will be held at Porto Alegre in Brazil in 2015 (Conference Chair: Dr. Acir Loredo-Souza). The date and venue for the 12th Americas Conference on Wind Engineering (12ACWE) were also announced during the ICWE. The 12th ACWE will be held from June 16-20, 2013 at Seattle (Conference Co-chairs, Drs. Dorothy Reed and Anurag Jain). Other upcoming conferences/symposium/workshops are the 15th Australasian Wind Engineering Society Workshop, February 2012, Sydney, Australia (Contact: AWSE15@awes.org), European-African Conference on Wind Engineering, July 7-11, 2013, Cambridge, UK (Contact: eacwe2013@nottingham.ac.uk), the 7th International Colloquium on Bluff Body Aerodynamics and Applications, September 2-6, 2012, Shanghai, China (Contact: Dr. Yaojun Ge), and the 8th Asia-Pacific Conference on Wind Engineering (APCWE-VII), December 10-14, 2013, Chennai, India (Chair: Dr. Nagesh Iyer). The deadline for paper submission for the ATC-SEI Advances in Hurricane Engineering Conference is Sept. 9, 2011 (see AAWE Web site and insert in this newsletter). Those who attended ICWE witnessed the awards ceremony at the banquet where several members of our community were recognized by IAWE awards. On behalf of AAWE, I want to congratulate all of the award winners.

Wind-related tragedy struck once again this year with the collapse of the outdoor stage during the Indiana State Fair on August 13, 2011 causing 5 deaths and several injuries. The killer was a gust front this time with wind speeds estimated above 70 mph as per the news sources. There was another stage collapse in a storm in Belgium during this week causing casualties and injuries. The two collapsed structures and events have strong resemblances. They were temporary structures made out of light trusses. I observed that these structures are surrounded by other structures and densely packed with people in their immediate vicinity during the collapse. While investigators will find the actual cause of the collapse, I wonder about the roles of the interference effects of the surrounding buildings and increased turbulence from the people (acting as roughness elements) in amplifying the wind loading. It occurred, perhaps, because it was a fatal combination of many factors that often come together to play a role in such disasters. I just hope that the society at large will pay more attention to the power of wind when it comes to the safety of human lives. They are certainly paying more attention when it comes to generating electrical power.

Sincerely,

Partha P. Sarkar
(515) 294-0719
ppsarkar@iastate.edu

AMERICAN ASSOCIATION FOR WIND ENGINEERING
WWW.AAWE.ORG
1415 Blue Spruce Drive
Fort Collins, CO 80524
Ph: 970-221-3371
Fax: 970-221-3124
E-mail: aawe@aawe.org

American Association for Wind Engineering

Objectives:

- The advancement of science and practice of wind engineering.
- The solution of national wind engineering problems through transfer of new knowledge into practice.

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American Association for Wind Engineering
1415 Blue Spruce Drive
Fort Collins, CO 80524
USA