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In This Issue

Insights on Wind-Driven Water Entry: Tests Conducted at the IBHS Research Center

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Figure 1: The duplex test house after roof shingles were blown off showing sealed (taped) sheathing joints on the left-hand-side unit and unsealed sheathing joints on the right-hand-side unit.

Interior water damage from wind-driven rain events results in significant property damage and can force people out of their homes for weeks and possibly longer. Once water gets inside, it can cause extensive damage to interior finishes, furnishings and other contents. In the worst cases, wind-driven rain can eventually lead to ceiling collapse when the insulation is saturated.

In August 2011, the Insurance Institute for Business & Home Safety (IBHS) conducted a full-scale examination of how wind-driven rain penetrates common types of openings in residential roof systems. The study was modeled on post-event damage assessments in areas where winds were strong enough to blow off the roof covering and underlayment but not the sheathing.

The objectives of this research project included:

- Quantifying the relative volume of water entering through different roof and attic openings.
- Demonstrating effective loss mitigation techniques, such as sealing the roof deck.

The building designed and constructed for this project was a duplex identical on both sides, except sheathing joints on one half of the roof deck were sealed prior to installing roofing materials and the other half was not sealed. Both halves of the roof were covered with felt paper underlayment prior to installing asphalt composition shingles (Figure 1). The building included gable ends fitted with gable end vents and 1 ft wide soffits at the eaves. The interior of the building was finished with wall board, ceiling drywall, carpet, linoleum, laminate flooring, and cabinetry. Each side was furnished with items commonly found in a bedroom, living room and dining room.

Establishing Wind-Driven Rain Capabilities

Planning and research leading to the development of wind-driven rain capabilities at the IBHS Research Center have been in progress for several years. Recognizing that a realistic distribution of droplet sizes is required to achieve the same wetting patterns on buildings that occur during actual storms, IBHS provided support to the University of Florida (UF) to assist with deployment of a research disdrometer in Hurricane Ike to measure and analyze the rain droplet size distribution. Additional support was provided to test commercially available spray nozzles in the UF wind simulator, which were later installed to produce a similar distribution of rain droplet sizes in the IBHS Research Center test chamber. Validation tests demonstrated that the target rain deposition rate of 8 inches per hour and the droplet size distributions were properly reproduced in the IBHS Research Center's test chamber (Figure 2).

Figure 2. Wind-driven rain being blown onto the duplex test house inside the IBHS Research Center's test chamber.

Measuring Water Entry Rates

When the duplex was completed, drainage panels and tracks (Dry-SpaceTM) were installed to create water collection channels between the ceiling trusses (Figure 4). These channels were outfitted with drains and pipes, which allowed collected water to be captured in plastic containers arranged throughout the interior (non-attic) space in the two sides of the duplex (Figure 5). The drainage system was installed in a modular system, which allowed the collection of water in ceiling areas that measured roughly 10 ft long by 2 ft wide. The trusses ran from front to back of the house and the 22.5 inch space between the trusses was divided into three sections, each about 10 ft long. Each drainage channel directed water to a separate numbered plastic container. Tests were typically conducted for a 20-minute period, during which a constant wind speed was maintained and the rainfall rate was set to produce 8 inches per hour on the test building. This simulated horizontally wind-driven rain. At the completion of each test the amount of water collected in the buckets was recorded.

While the roof covering was still in place, tests were conducted to determine water entry amounts through gable end vents and the soffited eave area. Water entry in the soffited eave area was evaluated with a vented vinyl soffit material installed and with this soffit material removed (Figure 3). After the roof covering had been removed, water entry though the sealed and unsealed roof deck was evaluated. Water entry data for this test was collected with the back side of the duplex facing the wind-driven rain, as shown in Figure 2. The roof shingles on this exposure were manually removed using roofing shovels to expose the deck surface. In another test, the shingles on the front of the duplex were blown off, and the front side was exposed to the wind and rain.

Figure 3. The under-eave area of the duplex test house with the vented vinyl soffit material removed.

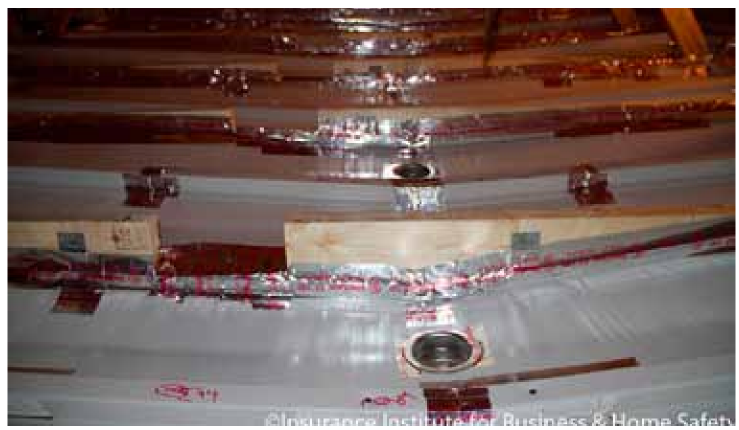

Figure 4. The drainage system installed in the attic of the duplex test house.

Figure 5. The water collection system located in the occupied space of the duplex test house.

Water Entry – Results and Discussion

A summary of the results for the gable end and soffited eave tests is given in Table 1. Two wind speeds were typically used for these tests. For the soffited eave tests a quartering wind exposure also was used. These results indicated that water entry through the soffited eave increased with increasing wind speed and that considerably more water entry occurred when the soffit material was missing. The results for the gable end vent tests indicated that water entry was about equal to the wind-driven rain deposition rate on the area of the gable end vent – all of the water that hit the vent entered the attic space.

Table 1. Summary of the water entry results for the soffited-eave and gable end vent tests.

Opening	Wind Direction	Wind Speed (mph)	Accumulation (in/hr)	Accumulation (% of deposition)
Open Soffit	Head on	50	1.3	15
Open Soffit	Head on	70	2.9	33
Open Soffit	45	50	1.6	20
Vented Vinyl Soffit	Head on	50	0.08	1
Vented Vinyl Soffit	Head on	70	0.73	9
Vented Vinyl Soffit	45	50	0.05	0.6
Gable Vent	Head on	50	8*	100*

** Water penetration based on the area of the gable vent.*

Once the roof shingles had been removed, the duplex was tested again to determine the effectiveness of sealing the joints between the roof decking with tape. The comparison between the sealed and unsealed roof decks was conducted with the rear of the duplex on the windward exposure (Figure 2). In this orientation, the part of the collection system that received most of the entry water (85%) was the same as those that accumulated water during the soffited eave tests. Comparisons were made between the volume of water entering through the sealed and unsealed roof deck to that collected in the open soffit test at 70 mph were made. The findings show four times the volume of water entered through the sealed deck side and 13 times the volume of water entered through the unsealed side. The volume of water entering the attic through the unsealed roof deck was approximately 3.5 times that entering through the sealed deck. It was visually observed during this test of the side of the duplex where shingles were removed manually and where water quantities was measured that water entry occurred at some joints and nail holes on the sealed side of the duplex, where the tape had been damaged by manually removing the shingles with roofing shovels. It was confirmed by inspection after the test that the tape at these locations exhibited cuts that allowed wind-driven water to enter. It was also observed in the later demonstration test that on the front side of the duplex where the shingles were blown off (Figure 1), nails tended to stay in place, reducing the nail hole drips and there were no cuts in the tape that produced additional water entry.

In a second test of the effectiveness of sealing the roof deck, the water collection system was removed from the attic and insulation was installed. The duplex was oriented with the front facing the wind and rain. Following this test of the sealed versus unsealed roof decks, IBHS brought in an experienced property insurance claims adjuster to estimate the amount of damage to each side of the duplex suffered. The adjuster assessed damage to the rooms on the windward side of both sides of the duplex, including the kitchen, dining room and family room. The difference in estimated repair costs was substantial. The side without a sealed roof deck resulted in property damage costs that were more than three times the amount for the side with the sealed roof deck. The furniture in the side without a sealed roof deck required replacement, while furnishings in the side with the sealed roof deck only required cleaning. Figures 6 and 7 depict the water entry and resulting damages from this test.

Figure 6. Water entry through can lights in the side of the duplex test house with the unsealed roof deck.

Figure 7. A portion of the ceiling collapsed on the side of the duplex with the unsealed roof deck, after the attic insulation became saturated.

The tests performed at the IBHS Research Center illustrate the importance of protecting building openings from wind-driven rain. These protections include securely attaching the soffit material so it will remain intact in high winds and covering gable end vents when a storm is forecast. Preparing long before a storm is also critical. When installing a new roof, adding tape to seal the joints between the roof sheathing before installing the underlayment and roof shingles will greatly reduce the amount of water entry. Installers should take care not to damage the tape during installation to provide the best protection. By limiting the amount of water that enters the structure, it is possible to limit the damage to a structure and its contents during a wind-driven rain event.

For more information on IBHS engineering and the IBHS Research Center, visit DisasterSafety.org.

Applied Technology Council Board Visits IBHS Wind Tunnel

By Leighton Cochran

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In late October I was fortunate enough to visit the impressive IBHS (an AAWE Corporate Sponsor) facility in South Carolina run by Tim Reinhold. The ATC Board held its quarterly meeting there with the fine hospitality of Tim and his team. This very impressive facility has been built by the insurance industry with a view to improving many aspects of the built environment. The 40 M$ campus has the full-scale, 2000 m^2, test chamber as its central focus. This building (designed by Walter P. Moore) has 105 fans that can generate Category 3 winds within the 18 m high test chamber. Each fan is 1700 mm in diameter and has 16 blades. The full-scale structures are placed on the 17 m concrete turntable before being exposed to wind, rain, fire, or some combination of all three. A more detailed discussion of the full campus is in the February 2011 edition of Structure Magazine, and videos of the decimation of some test buildings may be seen on U-tube.

Figure 1: Kurt Gurley at the intake side of the huge IBHS facility during the October ATC Board meeting.

2011 Coastal Construction Manual – FEMA P-55 Now Available

The 2011 Coastal Construction Manual, Fourth Edition (FEMA P-55), is a two-volume publication that provides a comprehensive approach to planning, siting, designing, constructing and maintaining homes in the coastal environment. Volume I provides information about hazard identification, siting decisions, regulatory requirements, economic implications and risk management. The primary audience for Volume I is design professionals, officials and those involved in the decision-making process.

Volume II contains in-depth descriptions of design, construction and maintenance practices that, when followed, will increase the durability of residential buildings in the harsh coastal environment and reduce economic losses associated with coastal natural disasters. The primary audience for Volume II is the design professional who is familiar with building codes and standards and has a basic understanding of engineering principles. For additional information on residential coastal construction, see the FEMA Residential Coastal Construction Web site at http://www.fema.gov/rebuild/mat/fema55.shtm.

Observing Wind Turbine Wakes using Research Radar

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Understanding the structure and evolution of turbine wakes is essential to properly plan wind farms and estimate wind turbine and farm efficiency. However, historical wind turbine wake observations have been restricted to limited LIDAR and tower studies. On 27 October 2011, Texas Tech University (TTU) deployed two mobile Ka-band (35 GHz) research radars to observe the structure and behavior of a wake generated from a three bladed megawatt turbine with 86 m rotor diameter and 80 m hub height. Preliminary observations from one of these radars (TTUKa1) are presented here.

The TTUKa radars collected several hours of coordinated horizontal plan-position indicator (PPI) and vertical range-height indicator (RHI) scans. Radar specifications for the deployment are provided in Table 1. TTUKa1 was located 2713 m north-northeast of the turbine (Figure 1). Because the prevailing wind direction during the data collection period was from the north, TTUKa1 was aligned upwind of the turbine almost parallel to the mean flow.

Table 1. TTUKa1 radar specifications.

Pulse Width (μs)	Pulse Repition Frequency (Hz)	Half-Power Beamwidth (°)	Gate Spacing (m)	Azimuthal (PPI) Resolution (°)	Elevation (RHI) Resolution (°)	Nyquist Velocity (m s^{-1})	Nyquist Range (km)
12	7500	0.49	15	0.352	0.1	16.2	20

The radar data presented were collected using two scanning strategies. Rapid PPI scanning occurred over a small horizontal sector containing the turbine and wake at a constant elevation angle of 1.2°. This scanning technique allowed for high-temporal resolution sampling (revisit times of approximately every three seconds) to assess horizontal wake evolution. At the location of the turbine, the beam of TTUKa1 emitted at an elevation angle of 1.2° was 56.8 m above ground level (Figure 1) and remained within the wake region for multiple kilometers downwind of the turbine. Repetitive RHI scans (vertical slices) over a small range of azimuths were also used and allowed for examination of the wake structure in the vertical dimension.

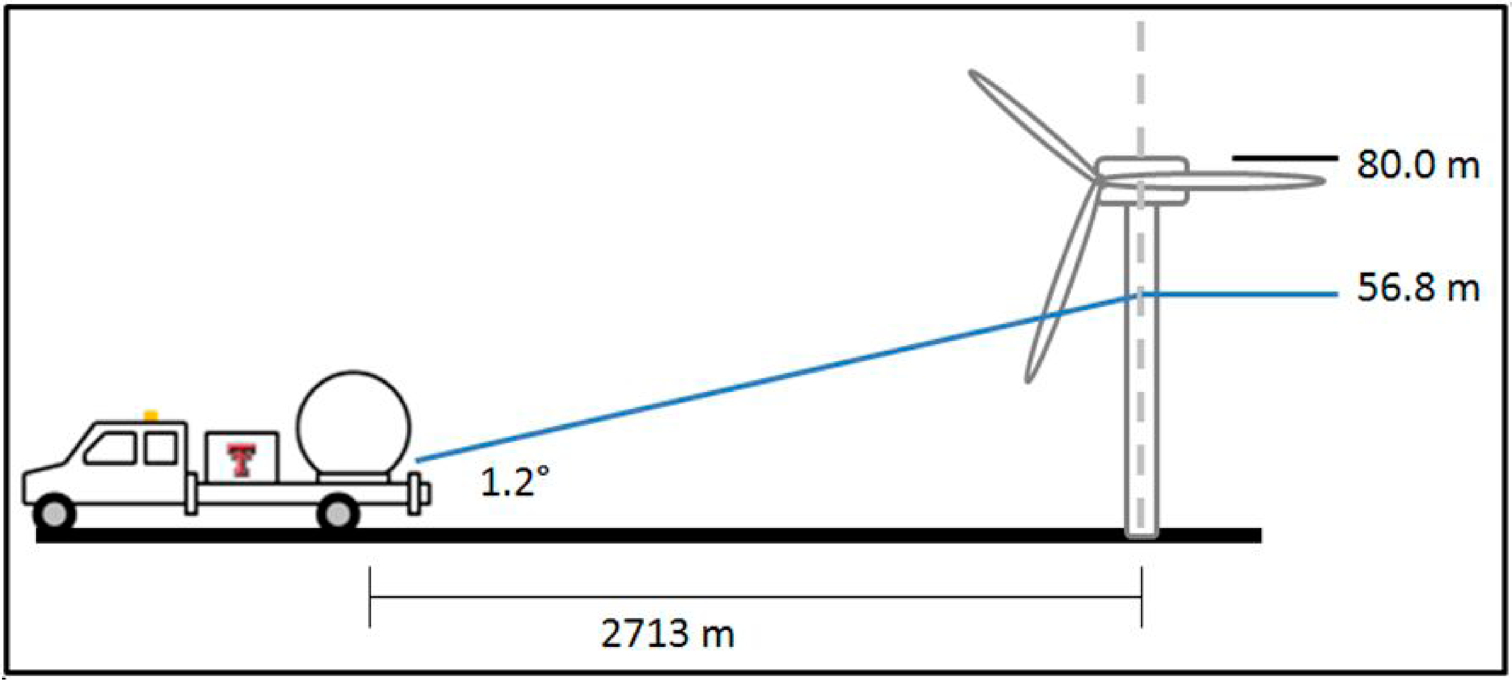

Figure 1. Schematic of the beam height from TTUKa1 at the location of the turbine based on a 1.2° elevation tilt.

Figure 2 shows a single PPI (horizontal) sector along with a corresponding composite of 100 scans (acquired during a five minute time period) from TTUKa1 of radial velocity and spectrum width (i.e., an indication of velocity dispersion within an individual radar sample volume). The location of the turbine is at approximately x = -1200 m, y = -2500 m, where there is a minimum in radial velocity and maximum in spectrum width (indicative of a ground target). There is also a meteorological tower 200 m downstream of the turbine (x = -1150 m, y = -2700 m) that appears in the data as a ground target. Preliminary analysis reveals that the flow comprising the wake within 200 m downstream of the turbine maintains deficits in excess of 35% of the ambient upstream flow. The wake influence is also evident for greater than 1300 m (or 15 rotor diameters) downstream of the turbine, and was evident even farther downstream during other data collection time periods. An increase in spectrum width is co-located with the reduced radial velocity region within the wake, representing increased turbulence within the entire wake region, and enhanced shear along its edges at the interface with the ambient flow.

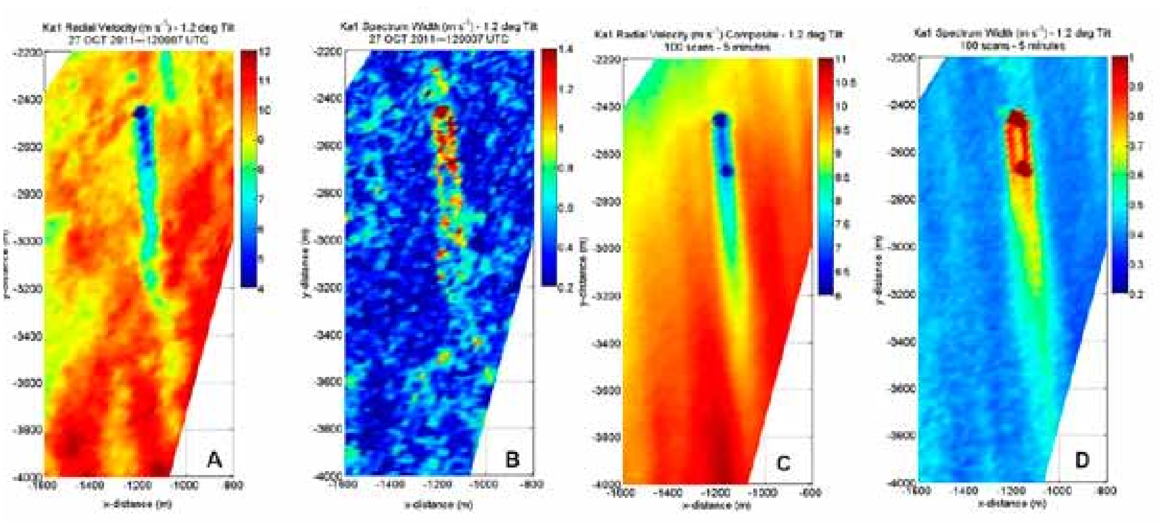

Figure 2. TTUKa1 individual PPI scan of (A) radial velocity (m/s) and (B) spectrum width (m/s). Composite fields constructed from 100 consecutive PPI scans (approximately five minutes) of (C) radial velocity (m/s) and (D) spectrum width (m/s) are also shown.

Figure 3 shows the composite mean radial velocity and spectrum width assimilated from 25 repetitive RHI (vertical) scans through the plane of the turbine. The turbine is located at range = 2700 m and the influence of the aforementioned metrological tower can be seen at range = 2950 m. Again, mean radial velocity deficits found downwind of the turbine are greater than 35% of the upstream values. Similar to the PPI analysis, the RHI spectrum width analysis also shows relative maxima on the peripheries of the wake.

Additional analyses are currently ongoing including an expansion of the PPI and RHI compositing efforts, and construction of dual-Doppler syntheses for the available domain to establish the mean structure of the full wind field. The various techniques will be used to establish the magnitude, spatial extent and evolution of the deficits within the wake region, as well as the meandering characteristics of the wake. The dual-Doppler analyses will also allow for the construction of vertical cross-sections through the wake region to help document changing wake characteristics with downwind distance from the turbine. This information will be beneficial to the wind energy community's efforts to optimize wind farm performance and meet the Department of Energy's initiative to produce 20% of the US electrical supply by 2030 using wind power.

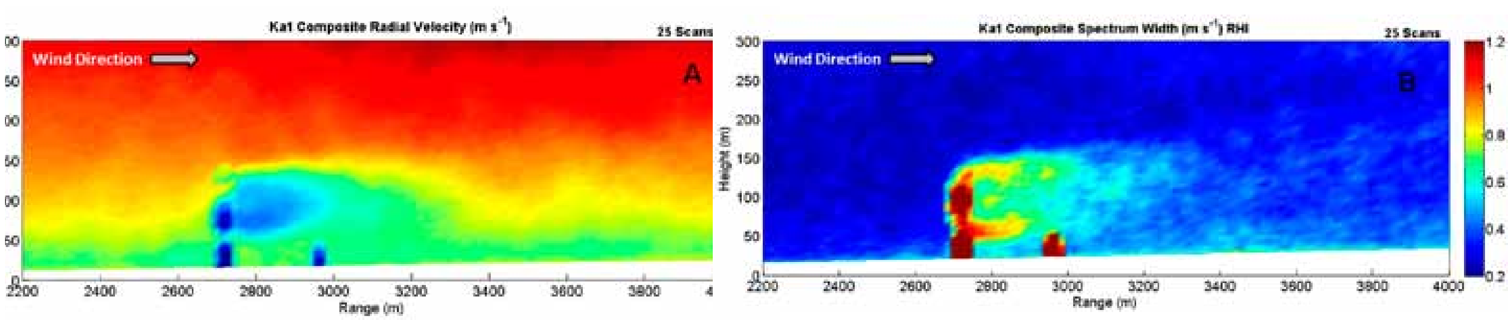

Figure 3. TTUKa1 composite RHI (A) radial velocity (m/s) and (B) spectrum width (m/s) for 25 successive scans.

President's Corner

Greetings. On behalf of AAWE, I wish you all a very happy and prosperous 2012. I sincerely hope that you had a wonderful and productive 2011. This past year will be remembered for multiple disaster-related and socio-political events that were quite unique. The good news is that it is all over.

First, I want to welcome the new AAWE members to this association and thank all the continuing members (individual and corporate) for their support through their 2012 memberships. I also thank all of those who contributed to the AAWE newsletters in 2011 by sharing their research findings and work of interest. The current newsletter has a theme of full-scale testing that we all know is extremely important. In this newsletter, there is an article on full-scale tests on wind-driven water entry in residential buildings conducted at the IBHS Research Center and another article on measurement of wind turbine wake using a research radar at Texas Tech University. I hope you will enjoy reading these articles.

Now I want to share a few highlights of AAWE-related activities in 2011 that follow.

- AAWE awarded travel grants to 16 graduate students, 2 postdocs and 9 faculty from 9 US universities and 3 Canadian universities to attend the 13th ICWE that was held in July 2011. A total amount of $22,870 was distributed including $3,300 from AAWE funds and the rest through a grant from NSF administered by JHU (courtesy of Dean Nick Jones).

- The AAWE Board of Directors meeting was held on July 14th for 2.5 hrs at Amsterdam during the 13th ICWE. The Board discussed several action items during the meeting including AAWE-related awards process, membership, newsletter/website, participation in damage-survey activities, conferences and workshop, finances and engagements with IAWE and other wind organizations. You can view the detailed minutes of this meeting on the AAWE website.

- Good progress has been made in the initial organizational setup for the 12th Americas Conference on Wind Engineering (12ACWE), co-chaired by Drs. Dorothy Reed and Anurag Jain, that will be held from June 16-20, 2013 at Seattle. AAWE sponsors this event by providing seed money. Preparations are also underway for the Third AAWE Workshop that is now scheduled to be held in summer 2012. It is being organized by Dr. Luca Caracoglia from Northeastern University. Details will follow soon. This workshop, held every 1.5 to 2 years, particularly encourages student participation. While I am on the topic of conferences, I want to remind you about the approaching deadline of Jan. 15, 2012 for abstract submission for the 2012 Joint Conference of the Engineering Mechanics Institute and 11th ASCE Joint Specialty Conference on Probabilistic Mechanics and Structural Reliability (EMI /PMC 2012) that will be held at the University of Notre Dame from June 17-20, 2012. This year's conference is organized by the members of our wind engineering community, Drs. Ahsan Kareem, Tracy Kijewski-Correa and Alexandros Taflanidis.

Sincerely,

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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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