

READING BETWEEN THE CONTOUR LINES OF THE WIND SPEED MAPS: Giving Tornadoes Their Due

BY BRUCE A. HALL, RBEC, Assoc. AIA, CDT; AND MATT B. PHELPS, PE, PhD

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INTRODUCTION

In the United States, extreme wind events occur each year, causing substantial physical harm to people and damage to the buildings they occupy. This article will provide design and construction-related professionals with U.S. inland historical data and suggested design options via possible future

wind speed maps. In the last 50 years, expenses related to extreme wind events have climbed into the billions of dollars per year for repair or replacement of property damage alone.

The cost estimates from the destruction related to extreme wind events are higher than most recognize since no one can accu-

rately calculate costs related to the loss of people and animals, especially pets. The more important question is this: Are we more concerned about the loss of property than the loss of human life? Both are obviously important because buildings that fail due to high wind speeds sometimes kill, maim, or injure the people inside.

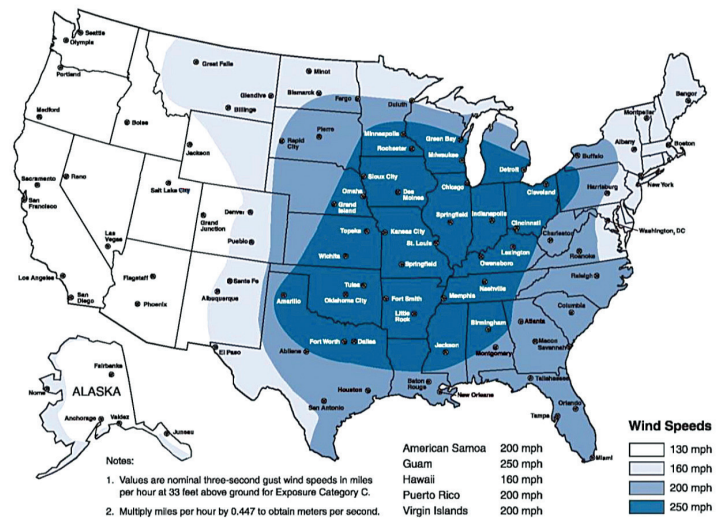


Figure 1A – Safe room wind speed map 2015 (courtesy of the ICC).

Figure 1B – FEMA map (courtesy of FEMA).

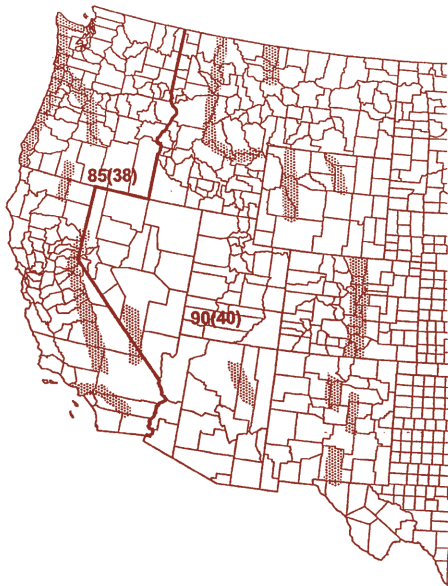
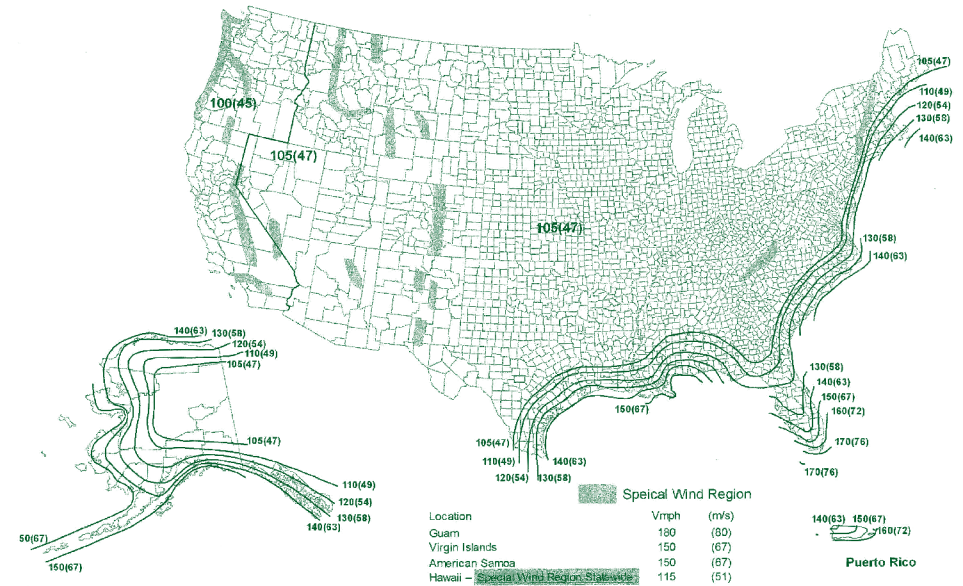


Figure 2A – ASCE 7 2005, western part of U.S. (courtesy of ASCE 7).

The use of statistical percentages for wind events is outdated, such as one tornado per a certain number of years (e.g., 50 or 300 years), and does not justify our current low inland wind speed maps. Therefore, the old statistical reasoning that promoted lower inland building-related wind speed maps is considered obsolete as a premise for this article. This article will provide some common-sense perspective to the question posed above and the suggested new wind maps that are reasonable based on historical data. International building codes already contain limited special wind zones, and more wind zones are proposed from other entities.

Our industry needs to adopt practical wind speed maps that correspond to historical extreme wind events. The old saying “speed kills” is applicable when discussing anticipated tornado wind speed forces on buildings and the safety of U.S. citizens. Based on the havoc unleashed by recent tornadoes (i.e., Joplin, MO, 2011), the latest International Code Council (ICC) codes responded to the extreme wind events by implementing codes for safe rooms that are based on recent wind speed maps (Figure 1A). Other organizations, such as the Federal Emergency Management Administration (FEMA), have adopted the codes for shelters (Figure 1B).

Safe rooms are a good starting point, but they are not enough to ensure the safety of people working or residing in these tornado-prone areas. In fact, safe rooms could be construed as discriminat-



- Notes:
1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10m) above ground for Exposure C category.
 2. Linear interpolation between contours is permitted.
 3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
 4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
 5. Wind speeds correspond to approximately a 15% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00333, MRI = 300 Years).

Figure 2B – ASCE 7 2010 Risk Category I. Also found in IBC 2012 code. (Courtesy ASCE.)

ing to those who are physically challenged and cannot make it to the designated safe room within the allotted tornado-type warning time. Per published data by the National Oceanic and Atmospheric Administration (NOAA) in March 2017, the time is limited—under 13 minutes’ notification on average—to find a safe room after an extreme wind event warning alert. In fact, safe room code development and related adoptions that have been code-implemented only support the claims made in this article that the current building code wind speed maps are insufficient for buildings in general and are in need of updating (Figure 2).

Wind Speed History and Code Background

The Gale Force Wind Speed Chart lists wind speeds from 32 to 63 mph and storm

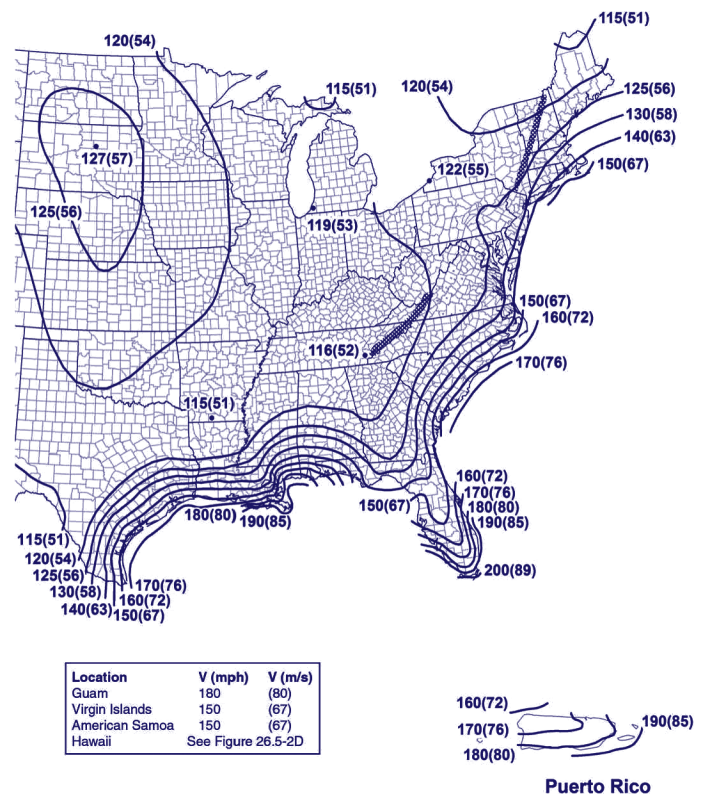


Figure 2C – ASCE 7 2016 Risk Category I (courtesy of ASCE 7).

force wind speeds from 64 to 72 mph. Regardless of charts, 32-mph wind events and the high end of the Enhanced Fujita (EF) Tornado Scale (EF 5, or above 200 MPH) will be the definition of an extreme wind force for this article.

Loss of life and property via extreme wind events has been primarily from

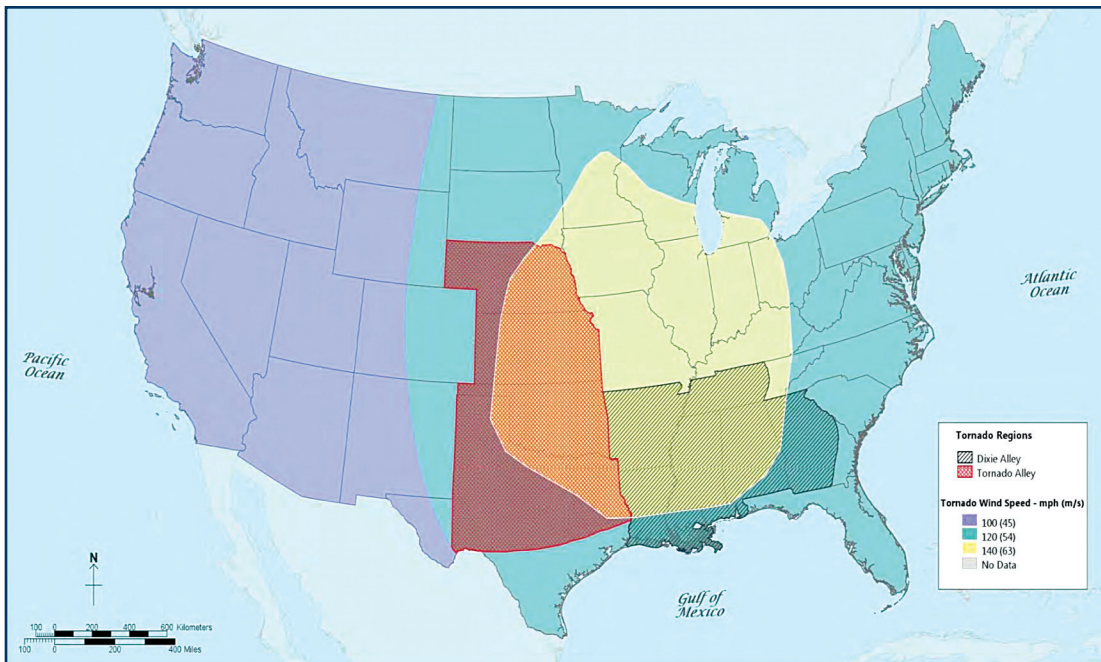


Figure 3 – FMG recommended wind speed maps (FMG Tornado Design Guidance Map 2015, courtesy of FMG).

horizontal rotational winds such as tornadoes and hurricanes. Other types of extreme wind events can be associated with derechos. A derecho is described as a fast-moving wind in a straight line or a cluster of wind downbursts with air microbursts within the cluster. Author Tim Marshall summarizes this point in stating, “Wind is wind” when discussing wind events. Regardless of the types of extreme wind events and their damaging effects on people or property, they have not been prominently recorded in ancient history compared to other natural disasters.

Scientists and archaeologists have unearthed evidence of ancient natural disasters through means of relative dating techniques and have communicated approximately when and where volcanoes, earthquakes, and flood events have occurred. That is not the case with extreme wind events. One of the rare accounts of an extreme ancient wind event is found in the ancient book of Job, chapter one, verse nineteen: “And behold, a great wind came from across the wilderness and struck the four corners of the house, and it fell on the young people and they died.” The book of Job dates to the 4th century BC or earlier. Most extreme wind events in history happened without leaving a trace except for the last few centuries, where there is some historical data. Excerpts of some events are listed below.

- In 1888 in the state of Iowa, a derecho was observed and published in

the *American Meteorological Journal* by Dr. Gustavus Hinrichs, professor of physics at the University of Iowa.

- Over 100 hurricanes hit the coasts of the U.S. in the 19th century, killing thousands and damaging property.
- An unnamed hurricane struck Galveston Island, Texas, on September 8, 1900, with virtually no warning. The death toll was staggering, with estimates from 6,000 to 12,000 lost.

In the 21st century, numerous design wind speed maps have changed slightly for distinct reasons, according to a committee of the American Society of Civil Engineers (ASCE). These changes are noted in the ASCE 7, *Design Guide for Buildings and Other Structures* standard. (Recent revisions have ensued in 2005, 2010, and 2016; see examples in Figure 2.) The recent wind speed map changes related to risk factors among the ASCE 7 publications have been confusing. Based on review of the wind speed maps over several editions of ASCE 7, wind speed map contour lines do not increase inland (noncoastal) for buildings and, therefore, are not proportionate to the recorded extreme inland wind events—at least in the last two decades.

Based on the evidence, it appears that the wind speed maps are largely discriminatory to the areas that are not along the coastlines or in the special wind regions

(shaded areas) on the ASCE 7 wind speed maps (Figure 2). Therefore, another question arises: Why are people and property along the coastlines (in hurricane zones) better protected by building codes than people and property elsewhere in the U.S.?

Governmental agencies such as FEMA and companies such as Factory Mutual Global (FMG) have developed their own extreme wind speed maps or adopted others that are mostly based on wind event historical data. FMG has recognized the deficiency of represented inland contour lines in the codes and has added a recommended wind

speed map that includes historical extreme wind event areas (recommended wind speed maps for tornadoes in the current FMG Data Sheet 1-28, Appendix D, Optional Guidance for Tornado-Resistant Design and Construction). See Figure 3. The recently produced map by FMG is similar to others that have made allowances for safe rooms, such as the 2016 ASCE 7, page 759, or the ICC map (Figure 1A).

The changes of the wind speed maps for safe rooms/shelters represent progress, but a recommendation would be the inclusion of a common-sense approach to create national wind speed maps for the entire building based on extreme wind event historical data. This approach would be much more comprehensive in addressing the safety of humans and animals in inland areas.

Historical wind speed data have only been a viable tool in recent history based on improvements in weather tracking and forecasting technology. A massive quantity of detailed historical wind speed data have been accumulated over the last 100 years from NOAA (and other weather entities) and is available for further analysis in relation to the inland states’ anticipated extreme wind speed killer events. Wind speeds are categorized via wind speed scales such as Saffir-Simpson for hurricanes and with the original Tornado Wind Scales Fujita (F) 1971, plus the Enhanced Fujita (EF) 2007 that were created to give perspective on wind destruction to buildings (Figure 4).

| ORIGINAL FUJITA SCALE | | ENHANCED FUJITA SCALE | |
|-----------------------|-------------|-----------------------|-------------|
| F5 | 261-318 mph | EF5 | +200 mph |
| F4 | 207-260 mph | EF4 | 166-200 mph |
| F3 | 158-206 mph | EF3 | 136-165 mph |
| F2 | 113-157 mph | EF2 | 111-135 mph |
| F1 | 73-112 mph | EF1 | 86-110 mph |
| F0 | <73 mph | EF0 | 65-85 mph |

Figure 4A – Tornado wind scales (EF post 2007).

| WEATHER SAFFIR-SIMPSON HURRICANE WIND SCALE | | |
|---|-------------|--------------|
| CATEGORY | WINDS (MPH) | DAMAGE |
| 1 | 74-95 | SOME |
| 2 | 96-110 | EXTENSIVE |
| 3 | 111-129 | DEVASTATING |
| 4 | 130-156 | CATASTROPHIC |
| 5 | 157+ | CATASTROPHIC |

Figure 4B – Hurricane wind scale.

Note: Hurricane/tornado scale wind speeds (or categories) represent minimum sustained wind speeds (via anemometer per a time unit) or wind speeds that have been determined by building or site damage in the aftermath. Hurricane/tornado scales are generally compared to other wind speed maps in this article (such as Figure 2 maps), which may or may not have the same methods to determine minimum wind speeds or categories of wind speed.

COMMON SENSE: HURRICANES VS. TORNADOES

Comparing hurricanes to tornadoes can be like comparing apples to oranges. Their most notable attributes—such as the storm tracks, duration, and size—can be very different. However, there is one comparable aspect between tornadoes and hurricanes: their destructive wind speeds. Hurricanes have a wide-swath footprint (often miles wide), with the top wind speed Category 5 exceeding 157 mph (sustained winds). Typically, tornadoes have a narrow-swath footprint (feet to one mile wide), with a top wind category EF 5, with winds greater than 200 mph (Figure 4).

On average, approximately 1300 tornadoes spin across the U.S. each year, and hurricanes hit our U.S. shore an average of approximately 1.75 times per year. Common sense leads us to pay attention to the wind speed facts of tornadoes versus hurricanes. Clearly, we should have as many protections in the codes for tornadoes as we do for hurricanes.

Tornadoes deserve wind speed map representation based on the destruction they dole out. According to the National Weather Service Storm Prediction Center, three Category 5 hurricanes have hit the U.S. mainland in known history, as follows:

1. 1935 – Unnamed Labor Day hurricane
2. 1969 – Camille
3. 1992 – Andrew

A complete list of F5/EF5 tornadoes from historical data by state are as follows:

- Oklahoma - Eight F5/EF5 tornadoes
- Alabama – Seven F5/EF5 tornadoes
- Kansas – Six F5/EF5 tornadoes
- Texas – Six F5/EF5 tornadoes
- Iowa – Six F5/EF5 tornadoes
- Ohio – Four F5/EF5 tornadoes
- Mississippi – Four F5/EF5 tornadoes
- Wisconsin – Three F5/EF5 tornadoes
- Missouri – Two F5/EF5 tornadoes
- Michigan – Two F5/EF5 tornadoes
- Illinois – Two F5/EF5 tornadoes
- Minnesota – Two F5/EF5 tornadoes
- North Dakota – Two F5/EF5 tornadoes
- Nebraska – One F5/EF5 tornado
- Kentucky – One F5/EF5 tornado
- Indiana – One F5/EF5 tornado
- Louisiana – One F5/EF5 tornado
- Tennessee – One F5/EF5 tornado
- South Dakota – One F5/EF5 tornado

Again, common sense would be to consider the use of the hurricane wind speed contour lines established by ASCE 7 for new tornado-related inland wind speed maps with respect to other risk factors such as building importance. For simplicity's sake, this article will not address the ASCE 7 calculations and factors to determine wind pressures per square foot on the exterior building cladding (zones 1-5 walls/roofs). Using hurricane contour lines as a basis could even raise the inland wind speed contour lines (mph) at isolated areas that warrant the new elevated wind speed con-

tour lines such as 150- to 300-mph areas (see example FMG map, Figure 3). Although some have stated that it is not economically practical to design new buildings to resist extreme wind speeds from tornadoes, it is noted by the authors of this article that eco-



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nominally practical building cost rationale is what has landed us in the predicament of losing a high number of people per year due to tornadoes. In retrospect, a compromise is needed, and it is needed now.

Since the U.S. historical weather data and forecasting was scanty in the early 20th century, wind event maps favored the coastal regions of the U.S., which is understandable, due to the massive loss of life by hurricanes. Fortunately, hurricane forecasting has improved in the late 20th century, and the loss of life due to hurricanes is negligible compared to the early 20th century—specifically relating to wind speed devastation.

Storm forecast improvements have impacted the building insurance industry. Insurance companies have a unique outlook on wind damage to property since they typically address claims for destruction to buildings. Insurance companies are interested in the latest information related to extreme wind event studies, especially those regarding tornadoes and hurricanes. Other weather-related entities have their own maps that represent historical extreme wind events (such as NOAA, with data dating back to the year 2000, as shown in *Figure 5*).

Which extreme wind events—hurricanes or tornadoes—are more devastating to peo-

ple and property over recent decades? An award-winning investigative journalist, Ed Leefeldt, wrote an article published by CBS Interactive Inc., entitled “Tornadoes Are Getting More Dangerous Than Hurricanes.” In the article, Leefeldt states that he attended the 2017 National Hurricane Conference in New Orleans and reports that the slimmer tornadoes are grabbing the headlines over the broader hurricanes. Further, Leefeldt stresses that the building insurance industry has observed extreme wind events that were destructive to buildings by conducting a 12-year study published in 2015. Leefeldt writes, “Another indication that this could be ‘the Year of the Twister’ comes from Verisk Analytics Property Claim Services, which provides data for the insurance industry. The average annual loss for the 12 years...from ‘severe convection storms,’ a.k.a. tornadoes, was \$11.23 billion compared to \$11.28 billion for hurricanes.”

The study answers the hot-topic question about which type of storm—hurricanes or tornadoes—causes more damage to buildings according to real dollars over a comparative 12-year time frame. Tornadoes and hurricanes are both recording slightly over \$11 billion per year in property loss, the study reported. Therefore, the loss of

human lives becomes the critical research question.

Other important statements made in the Leefeldt article referring to the 12-year study are quoted as follows:

- Hurricane damage and deaths are attributed largely to the storm surge and flooding that the winds blow ashore, said the Weather Channel, accounting for 88 percent of the fatalities compared to 11 percent for wind.
- This year’s hurricane conference will come to grips with all these issues in the city where the memory of Katrina still lingers. But a recent February cyclone with 150-mile-per-hour winds tore a 10-mile path across the Crescent City, injured 33, and turned out the lights for 10,000 people.

According to the National Weather Service (NWS), between 2008 and 2017, U.S. fatality averages are recorded as 10 deaths per year for hurricanes and 101 deaths per year for tornadoes. The basic math (using 11% hurricane wind-related human life lost) reduces hurricane deaths by wind down to approximately one per year on average between 2008 and 2017. These startling differences between tornado and hurricane-related deaths are eye-opening (*Figure 6*).

It is understood that hurricane versus tornado statistics are different over 50 years, but the old data are skewed based on old hurricane forecasting technologies. Over the last ten years, the data show that tornado-related deaths per average year outscore hurricane-related deaths 101 to 1.

If we draw extreme wind speed map contour lines related to safety of people in buildings for the U.S. areas that represent approximately one human death per year on average, and

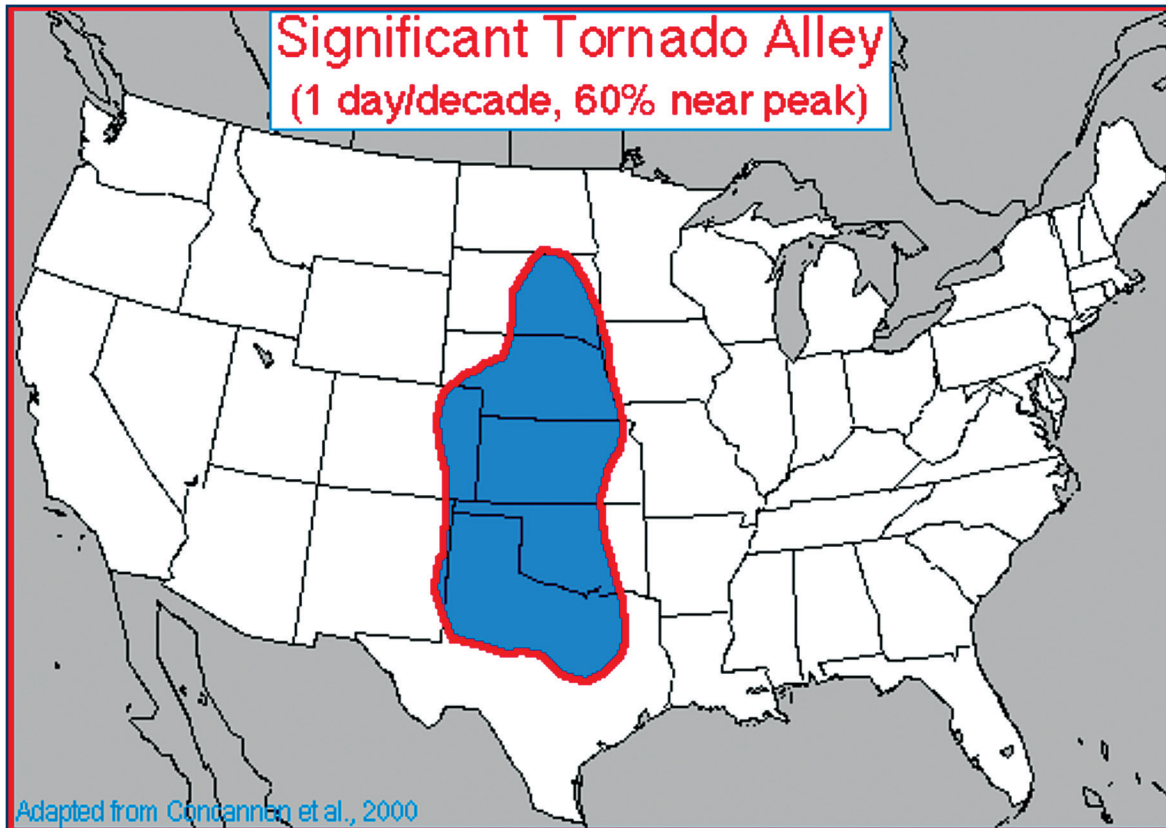


Figure 5 – Source: NOAA (courtesy of NOAA).

we ignore the areas that represent approximately 101 human deaths per year on average, then do those coastal extreme wind speed contour lines reflect our values of safety?

The reality is that tornadoes have become a major problem for our inland states due to the lack of tornado forecasting and limited warning alerts. The good news is that hurricane forecasts have improved since 1900, and now we have forecasts of days, not minutes, before hurricanes/tropical storms hit the U.S. The technology has made a profound difference, to date, in the number of deaths since the 1900 hurricane swept Galveston, Texas.

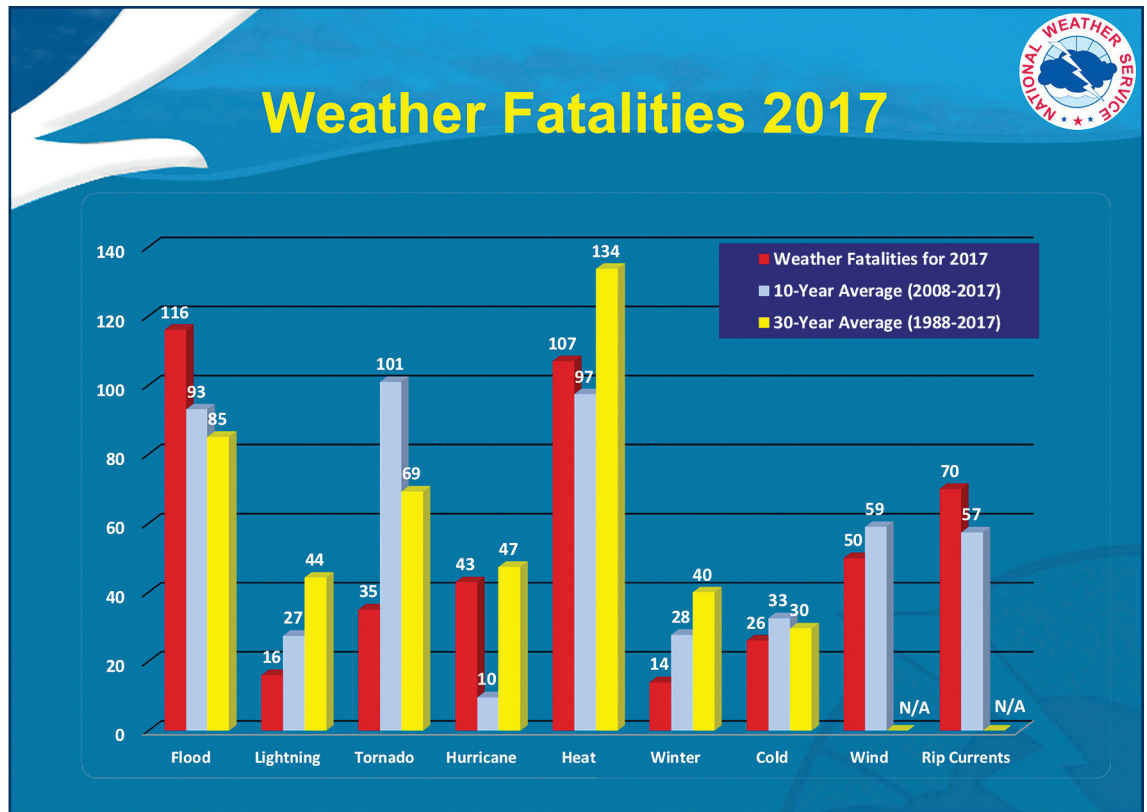


Figure 6 – Weather fatalities 2017 (courtesy of the NWS).

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Why are people and property along the coastlines (in hurricane zones) better protected by building codes than people and property elsewhere in the U.S.?

it is better than no warning at all. Other natural disasters, such as earthquakes, provide even less warning before a jolt to a building structure.

EARTHQUAKES COMPARED TO EXTREME WIND EVENTS

A possible comparison to extreme tornado wind events are the earthquakes that happen each year in the U.S. and the corresponding earthquake seismic maps in the building codes. Earthquake codes adopted years ago increased building costs to building owners. Our seismic scientists in 2018 cannot predict earthquakes with any certainty. However, the scientists are confident that earthquakes will happen again, and their warning is for us to be as prepared as possible to save lives and property. The fact remains that we have no guarantees when or where earthquakes will happen, but we still have developed minimum building codes based on seismic maps that influence the design and costs of new buildings. Those choosing to build in the U.S. earthquake zones (per 2015 or 2018 codes) must build to a minimum code requirement in order to minimize damage in the event of an unpredicted earthquake that might occur near a newly built building.

The U.S. has coastal and inland earthquake zones, yet the U.S. does not have building codes in place for the inland areas to resist high wind events such as our coastal high-wind event regions (see *Figure 2*). There are limited inland areas shown on

WIND EVENT FORECASTING TECHNOLOGIES

The loss of life related to hurricane-related extreme wind events has diminished drastically due to the development of technology and forecasting of hurricanes—even in the last 50 years. The 20th-century hurricane scales invented in the 1970s were based on damage in the wake of the storms. After storms were assessed and analyzed, the estimated wind speeds were relegated to categories. The idea of determining maximum wind speed of an extreme windstorm with wind speed measuring devices such as the anemometer was developed later. In

the 21st Century, the anemometer is in use for storm warning forecasts, which still are released just a few minutes prior to a tornado touching down. Time is of the essence to attempt to get to a safe spot before tornadic extreme wind events strike.

A visitor trying to find the new technology safe room minutes after a tornado warning siren has gone off—often in an unfamiliar building and even with well-lit and posted hallway maps—could be frustrated. Even once a person has reached the safe room entrance, there could be a long line to get through a narrow door. A few minutes is not much time to find shelter; nevertheless,

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the current building code wind speed maps called Special Wind Regions (shaded areas) that indicate extreme wind zone areas that are typically associated with mountainous regions (Figure 2). The inland wind speed research data have been collected and presented by our weather organizations, such as NOAA, for years. The data indicate where and when the wind events have occurred in past years. Our industry should consider interpreting the 21st-century known data in relation to where future tornadoes or extreme wind events will most likely touch down to protect people first and, secondarily, property assets. The wind data collected and codes developed for wind events should be like the current seismic code—meaning designed wind speed map contour lines with-in reason. This article proposes common-sense extreme wind speed maps related to extreme wind speed maps for buildings that are consistent with the historic wind speed events and are safety-focused.

As a construction industry, we have spent countless hours promoting personal safety. We have heard leadership speeches about how valuable personal safety is to our companies, our families, and ourselves. The shared U.S. goal of our national organizations, such as the Occupational Safety and Health Administration (OSHA), is that everyone goes home safely. Yet, what about safety in our homes from earthquakes and extreme wind events? Is new residential or commercial construction excluded from seismic building codes in various U.S. inland states that have had earthquakes? No! Inexplicably, we have failed to use the historical tornado location data to our own advantage, and we continue to build as though the extreme wind data do not exist.

There will be future wind events that will kill hundreds unless something is accomplished to prevent the devastation of life. The wind events—like earthquake events—are not predicable, but they will strike in specific U.S. regions just as they have historically, as recorded by NOAA. The actuarial science and climatology confirm the locations at enhanced risk. Americans living in coastal or seismic zones have suitable building code responses to the enhanced risks in their respective areas. Why haven't the building codes changed in response to similar wind risks in the country's interior?

EXTREME WIND EVENTS: FACTS AND FIGURES

The research for this article focuses on the safety of people in our society who do not have reasonable building protection from extreme wind events. If you read between the contour lines of the current ASCE Chapter 7 wind maps, it sends a clear message that the people and property along our coastlines are more protected from high wind events than people and property inland who have similar or more

extreme wind events. It is quite likely that possible future wind speed maps that fairly represent the historical extreme wind event data will not be totally accurate and will require updating periodically, just as earthquake-related seismic maps are updated.

Seismic maps are not totally accurate and need continual updating. In July 2014, an article entitled "Earthquake Maps Reveal Higher Risk for Much of the U.S.," written by Brian Howard with the National Geographic Organization, was published to illustrate



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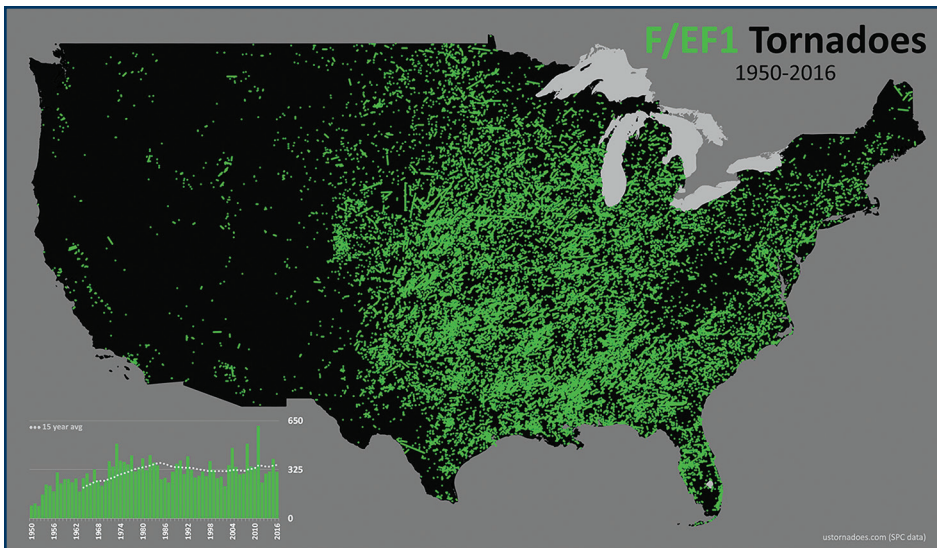


Figure 7A – F/EF1 tornado treks in U.S. mainland (courtesy of the Storm Prediction Center, ustornadoes.com).

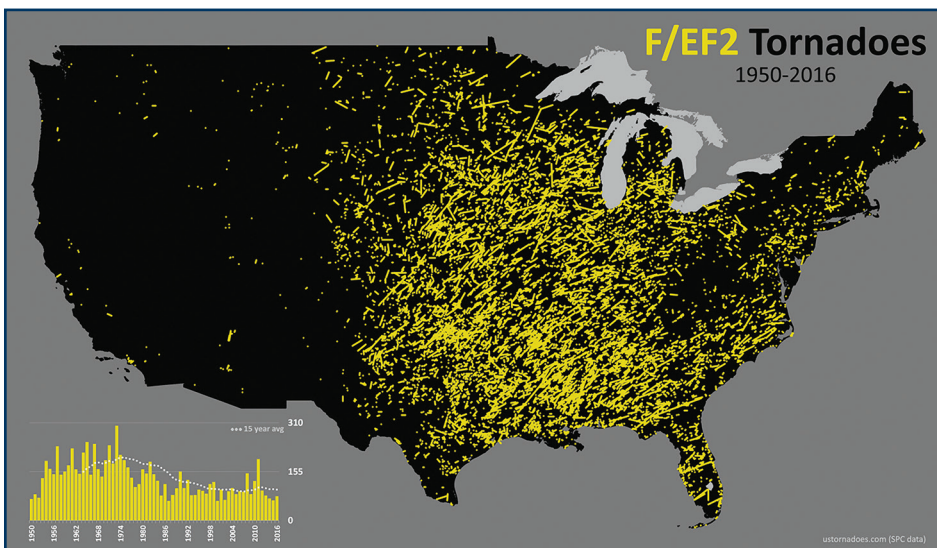


Figure 7B – F/EF2 tornado treks in U.S. mainland (courtesy of the Storm Prediction Center, ustornadoes.com).

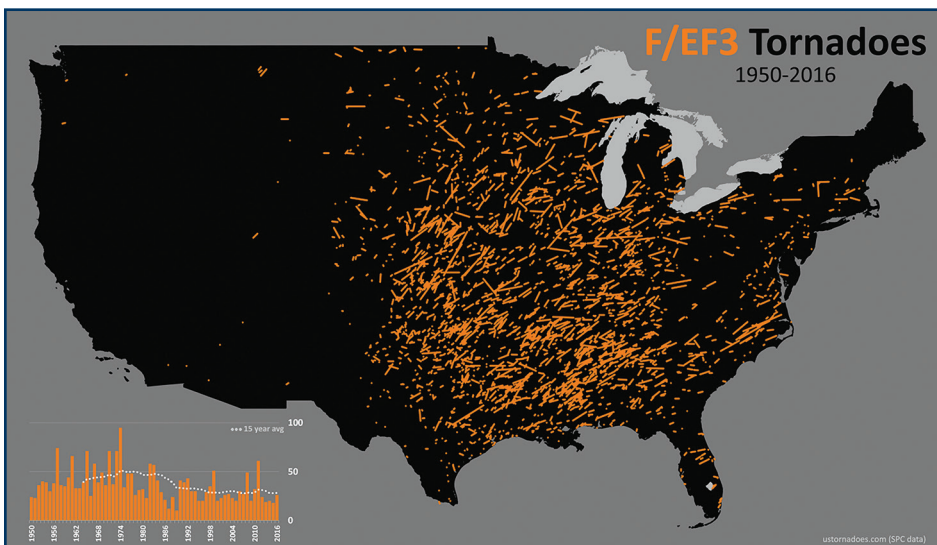


Figure 7C – F/EF3 tornado treks in U.S. mainland (courtesy of the Storm Prediction Center, ustornadoes.com).

the inaccuracy of earthquake maps. The article addresses the fact that earthquakes have occurred with higher readings on the Richter Scale than some building code seismic zones. For example, the article cited a 2011 Virginia earthquake that was more powerful than the seismic maps had anticipated. The Virginia earthquake caused damage to the Washington Monument nearby. Howard also indicates that the Building Seismic Safety Code Council (BSSCC) was revising new seismic maps to include the recent earthquake events. In perspective, in the U.S., from the years 2000 to 2017, there have been four recorded human deaths related to earthquakes and over 1400 killed due to tornado-related extreme wind events alone.

Maybe our country should take note from the Building Seismic Safety Council (BSSC) established by the National Institute of Building Sciences (NIBS) and create a Building Extreme Wind Event Safety Code Council (BEWESCC). If we create a BEWESCC and lobby to adopt a new inland U.S. representative building code with extreme wind speed maps based on historical data (which translates into increased building pressures per square foot) through proper ASCE 7 calculation (zones 1-5 walls/roofs), what impact would it make on property losses? More importantly, how many lives would be saved if we implemented the more stringent extreme wind speed maps? How many lives would be saved through better-built buildings?

The year 2011 was one of the worst years on record for the loss of life and property caused by tornadoes. How many more people need to die before the changes are made to ensure safety from extreme inland wind events? Our friends at BSSC show an average of 5.5 human souls lost per year over the last 70 years in the U.S. Planning for devastating events is a must in our country, and hopefully in the next 70 years we can report, via the BEWESCC, a yearly average of less than five U.S. human deaths related to extreme wind events, a.k.a. tornadoes, and not a continued loss of 101 per year.

CLOSING


As building envelope consulting specialists, our common-sense approach should be to pose the right questions for extreme wind events and their potential human loss factor and building damage. Questions could be:

- What is our leadership role related

to extreme wind events as pertaining to safety?

- How should we continue to influence the current building codes for change?
- Should we anticipate pushback from owners, insurance companies, and “old-school” ratio statistics proponents who are against promoting more expensive extreme-wind-resistant buildings?

We simply must provide the money for safer buildings that will save lives in the extreme wind event regions. The intention of this article was not meant to cover every aspect of the tornado wind speed and safety conversation, but instead to hopefully provide a cursory executive review of needed change. There are many related issues that may need to be addressed beyond this article. For instance, there are special embedded topics that should be considered, such as the residential construction market, in general, and special mobile home and manufactured home components. However, we must start somewhere, and the commercial, industrial, and public building market is ready for the inland extreme wind speed changes according to reasonable high wind speed contour lines.

Drawing contour lines that encompass the bulk of extreme historical wind events shown on each map (F5/EF5, F4/EF4, F3/EF3, F2/EF2, F1/EF1 in *Figures 7A-7E*) would be a positive for better wind-resistant buildings. Maybe our building industry could use the example put forth from the recent energy codes, which have slowly implemented more stringent codes over the years (three-year increments since 2006). It is understood that some will still argue that the building costs for safety are too high to overcome. As mentioned above, the facts speak for themselves, and our society over the next 70 years will be judged based on our decisions to protect the public. Some readers of this article will remember that their charge as designers is to protect the public. The facts have been established, and they can be easily researched by those who choose to take the time to become educated. New extreme wind speed maps that promote new building codes soon can make a significant difference in the loss of life, because approximately 1300 tornadoes will rip across the U.S. each year for the foreseeable future. 

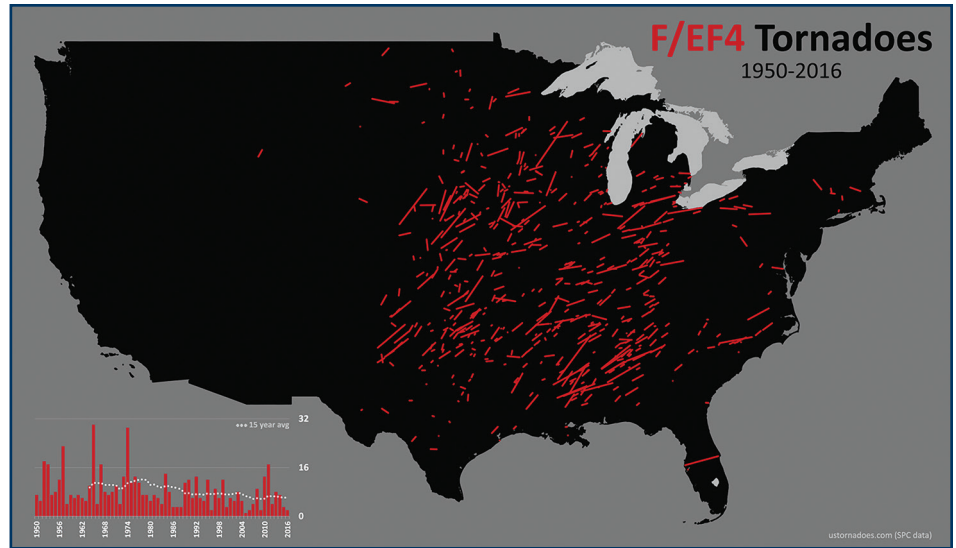


Figure 7D – F/EF4 tornado treks in U.S. mainland (courtesy of the Storm Prediction Center, ustornadoes.com).

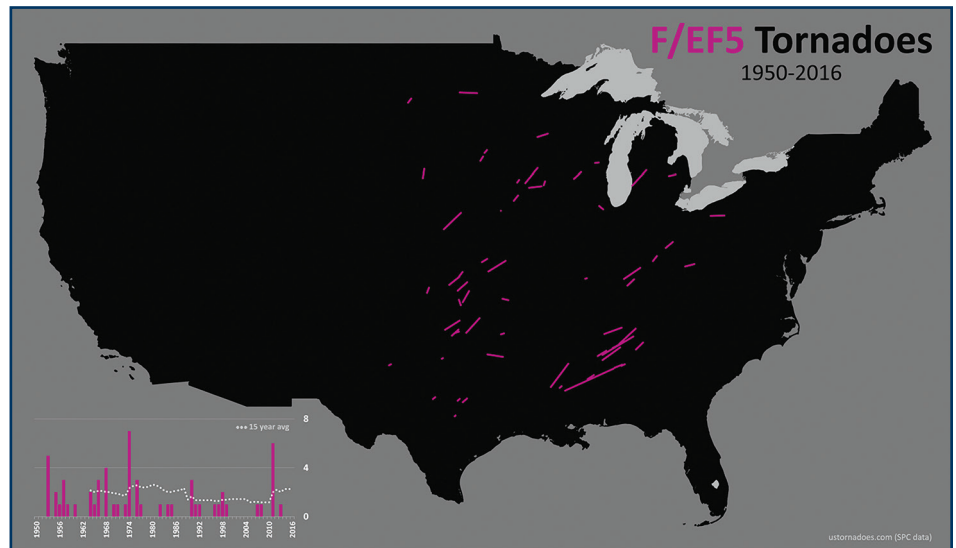


Figure 7E – F/EF5 tornado treks in U.S. mainland (courtesy of the Storm Prediction Center).



Bruce A. Hall

Bruce A. Hall is a senior facilities professional for Terracon Consultants, Dallas, Texas. He has served as a building envelope consultant for 33 years, along with earning a degree in architecture from Texas

A&M University and a master’s degree in archaeology from Southwestern Seminary. He is a building envelope consultant, published author, archaeologist, and educator. As an industry leader, Hall was a founder and 1990 president of the Gulf Coast Roof Management Institute, which later merged with the Gulf Coast Chapter of RCI (RCIGC).



Matt B. Phelps

Matt Phelps received his PhD degree from Texas Tech University in December 2018. The forensic investigator is involved in various research activities related to damage to building envelopes and structural systems,

and mathematical modeling of natural systems. He received a Top Paper award at the 2012 American Association for Wind Engineering international conference for wind versus flood damage energy load analysis and sequencing. Phelps is a member of RCI.