Database-assisted design, standardization, and wind direction effects

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DATABASE-ASSISTED DESIGN, STANDARDIZATION, AND WIND DIRECTION EFFECTS

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ABSTRACT: The writers present a simple methodology, developed for use in design assisted by electronic aerodynamic and climatological databases (for short, database-assisted design), that allows a realistic assessment of wind directionality effects. The methodology is applied to typical low-rise industrial steel frame buildings with a rectangular shape in plan, located in hurricane-prone areas, and results are compared with results obtained by the procedure specified in the ASCE 7-98 Standard, which, for buildings, consists of applying a blanket directionality reduction factor $K_d = 0.85$ to wind effects obtained by disregarding directionality. The results show that, for significant numbers of buildings in hurricane-prone areas, the use of the ASCE procedure can result in the underestimation of wind effects corresponding to strength design. They also show that database-assisted design for wind loads offers the potential for significantly more risk-consistent, safer, and economical design for buildings with both known and unknown orientation.

INTRODUCTION

Wind directionality effects raise design and codification issues that have received increased attention in recent decades. The British Standard BS 6399 Part 2 (1995) and the ASCE 7-98 Standard (1999) are among the standards that make explicit allowance for such effects. In this paper, the writers present a contribution to the wind directionality problem based on a methodology proposed for the development of electronic standard provisions for wind loads (Simiu et al. 1993; Whalen et al. 1998). Following a description of our approach, the writers present results obtained for a typical low-rise industrial building.

The objective of electronic provisions for wind loads is to allow the use in design of large aerodynamic databases containing time series of pressures measured in the wind tunnel at a large number of points on the building surface. If available, climatological databases can also be used. The use of databases is referred to here as database-assisted design and is accepted by the ASCE 7-98 Standard (1999, Section 6.6.2, item 3) as an alternative to the use of wind pressure tables and plots.

The development within the last 100 years of tables and plots for estimating wind pressures was due to: (1) constraints on the amount of information storage inherent in conventional, printed standards; and (2) the limited information processing capabilities inherent in the use of the slide rule, the computational tool predominantly used by structural designers until about three decades ago. Since tables and plots summarize vast amounts of information in a few numbers, they tend to distort the wind loading picture and lead to designs that are not risk-consistent. In contrast, significantly more risk-consistent design for wind loading can be accomplished if time series of pressures measured in the wind tunnel are utilized to the fullest possible extent. The acceptance of database-assisted design by the ASCE 7-98 Standard followed from recognition of this fact.

Database-assisted design for wind loads in hurricane-prone regions is based on: (1) the development of technology for recording and compactly storing simultaneous wind tunnel or full-scale pressure time histories at as many as 1,000 pressure ports over the external and internal surfaces of building models; (2) the development of climatological databases containing large numbers of simulated hurricane wind speed data (see Appendix 2); and (3) computational capabilities allowing the use of pressure and climatological databases for the fast and user-friendly calculation of bending moments, shear forces, and axial forces in wind-resistant structures (Lin and Surry 1997; Whalen and Simiu 1998; Whalen et al. 1998, 2000).

Database-assisted design for wind loading can eliminate a substantial inconsistency inherent in current structural engineering practice as applied, in particular, to low-rise structures. Owing to the use of finite elements or other computationally intensive techniques, structural analysis methods for determining stresses in structures subjected to specified wind loads can in many instances be remarkably accurate—say, to within 5% or less. On the other hand, the wind loads themselves are specified in conventional standards much more crudely: deviations of wind effects based on current standard tables and plots from their values based on wind tunnel or full-scale measurements can be as high as 25 or even 50%. The use of state-of-the-art structural analysis methods in conjunction with conventional wind loading provisions therefore provides the illusion, rather than the substance, of good engineering design; many portions of a building are overdesigned, meaning that material is wasted, while other portions may be underdesigned, meaning that they—and the entire structure—may be exposed to unnecessarily high risk of damage or failure. Therefore, the intent of the ASCE 7-98 Standard—to protect buildings from damage or failure by specifying ''minimum loads''—is in many instances not realized. One example, related to the way the ASCE Standard 7-98 accounts for wind directionality, will be discussed in this paper.

The writers note, first, that database-assisted design would be more risk-consistent than design based on conventional standard provisions even if the data recorded in the aerodynamic databases covered no more than the relatively modest number of building configurations and dimensions used in past decades to develop standard tables and plots. However, assembling a comprehensive aerodynamic database is a continual process, and over time an increased database can further enhance this advantage.

Second, database-assisted design allows the structural characteristics of the structure (e.g., its influence lines) to be taken into account when calculating wind effects. This is not possible in design based on conventional standard provisions, such as those of the ASCE 7 Standard, since the latter were developed on the basis of generic, ''hard-wired'' structural in-

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puts designed to cover a large number of different structural parameters and types. In addition to being in many cases unrealistic, such ''hard-wired'' inputs may be a barrier to the development of innovative designs, that is, designs that would result in, e.g., more advantageous bending moment distributions.

Third, conventional standards specify, for all frames, the loading that affects the most unfavorably loaded frame and do not account for the effect of the distance between frames upon the fluctuating part of the load. In contrast, database-assisted design automatically accounts in a realistic fashion for the loading affecting each individual frame, including the dependence of the fluctuating part of the load on distance between frames. Depending upon the degree of load redistribution among frames, knowledge of the actual wind effects on each frame may offer the potential for additional economies in design, especially if automated design and fabrication methods are used.

In this paper, the writers focus on database-assisted design as applied to the directionality issue and show that it can account for wind direction more realistically than is the case for design based on conventional standards. For buildings, the ASCE 7-98 Standard does not differentiate between directional effects on cladding or components, on the one hand, and main wind-load resisting systems, on the other, even though the dependence of the wind load upon direction may be drastically different in the two cases. The ASCE 7-98 tables and plots cannot be used to take advantage of building orientations that are favorable with respect to the directional wind climate. They do not take into account (1) the dependence of wind directionality reduction factors upon the mean recurrence interval of the wind load [Simiu and Heckert (1998); see also Appendix I]; (2) the directional aerodynamic properties of the specific type of building being designed; and (3) the directional wind climate at the location of interest. Database-assisted design for wind loads can account for each of these three factors.

The writers present typical results of calculations of bending moments at various cross sections of frames of a common type of industrial building, first by disregarding and then by accounting for wind directionality effects. The results confirm that wind directionality effects depend upon the mean recurrence interval of the wind load, a dependence that is not considered in the ASCE 7-98 Standard. They also help to assess the adequacy of the value of the directionality reduction factor $K_d = 0.85$ specified for buildings by the ASCE 7-98 provisions (pp. 24, 25, 60, 115). The writers' estimates do not reflect sampling errors in the estimation of extreme wind speeds—due either to the relatively short length of the historical record on which climatological parameter estimates are based, or to the limited number of simulated hurricanes used in this work. Those errors constitute a separate issue dealt with in detail by Minciarelli et al. (2000). However, they do not affect the basic conclusions of our work, which would be the same even if they had been based on ''true'' wind speeds corresponding to various mean recurrence intervals or on larger number of simulated hurricanes. The fact that the writers obtained similar results for tens of stations is an indication to this effect.

The choice of the factor $K_d = 0.85$ is justified in the ASCE 7-98 Commentary by reference to Ellingwood et al. (1980). However, Ellingwood et al. mention this value in a tentative manner (p. 115), with no supporting material concerning its technical basis, no indication of primary or secondary sources, and no apparent intent to ascribe to it any definitive status. A tentative justification for a similar value was suggested by Davenport (1977), which is based upon statistics of winds unrelated to extremes. The writers believe that the database-assisted approach offers a useful approach for the assessment of the choice of the factor $K_d = 0.85$ in the ASCE 7 Standard and for the clear separation of directionality effects from other effects that this factor may have been intended to reflect.

COMPUTATION METHODOLOGY

The writers' methodology makes use of records of measurements made on a 1/200 scale model of a typical rectangular building with overall dimensions 30.48 × 60.96 m, 6.096 m eave height, and a two-slope roof with slopes 1/24. The measured data consist of time series of the fluctuating pressures sampled at 400 Hz for a duration of 60 s, corresponding to about 1 h in the prototype and recorded at about 500 pressure taps distributed over the entire building envelope. Pressure records are available for each of 37 directions, i.e., 0° (coinciding with the direction of the long axis of the building), 5°, 10°, . . . , 180° (Lin and Surry 1997; Whalen et al. 1998).

In addition, the methodology makes use of (1) the largest 1 min hurricane wind speeds at 10 m above ground in open terrain near the coastline, for each of the 16 azimuths in each of 999 simulated hurricanes (Batts et al. 1979); and (2) mean hurricane arrival rates estimated from historical records. This climatological database is recorded in National Institute of Standards and Technology public electronic files for each of about 50 locations on the Gulf and Atlantic Coasts (see Appendix II). To the writers' knowledge, no other publicly accessible files of simulated hurricane wind speeds are available. As shown by Heckert et al. (1998) and in Simiu and Scanlan (1996, p. 117), differences between estimates of hurricane coastline wind speeds by Batts et al. (1979) on the one hand and, e.g., Vickery and Twisdale (1995) on the other are in most cases small. Note that the use of 1 min wind speeds is due to historical reasons, but such use has no effect on the basic results, since whenever necessary the 1 min data can be transformed to 1 h (or 3 s, or fastest-mile) data by employing standard micrometeorological procedures.

The wind-force resisting structure consists of steel frames hinged at the column bases and placed at 7.62 m between centers. A schematic elevation of a typical frame is shown in Fig. 1. A plan view of the building and the locations of the

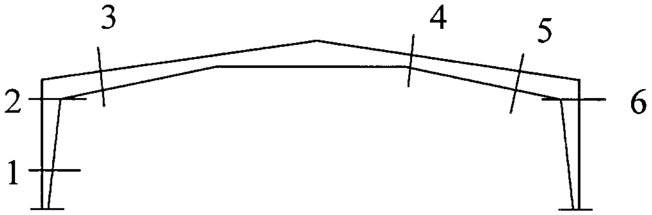

FIG. 1. Schematic View of Typical Frame, with Designation of Cross Sections

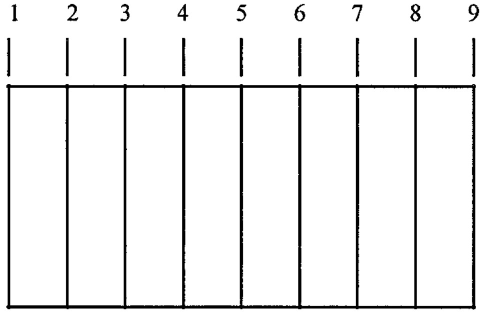

FIG. 2. Plan View of Frames, with Designation of Frames

frames are shown in Fig. 2. The frames were designed by G. Harris of CECO Building Systems using standard Metal Buildings Manufacturers Association (MBMA) software (Whalen et al. 1998).

The data are processed by the program WiLDE (Whalen et al. 2000), designed for routine office use. The program calculates fluctuating time histories and peaks of moments, shear forces, and axial forces at any desired number of cross sections in any of the frames of buildings of the type just described.

Calculations in Which Wind Directionality Is Taken into Account

The automated calculation sequence proceeds as follows. First, directional influence factors for bending moments are calculated. These consist, for each frame, of bending moments at various cross sections, induced by wind with a 1 m/s speed at 10 m above ground in open terrain, blowing from directions defined by 0, 5, 10, . . . , 360° angles. Following the calculation of the directional influence factors, the program calculates

TABLE 1. 50-year and 500-year Moments (kN-m) Estimated by Accounting for (Columns 1–16) and Not Accounting for (Column 17) Wind Directionality, and Directional Reduction Factor K_d (Column 18)

	Orientation																	
Moment	N-NE	NE	E-NE	E	E-SE	SE	S-SE	S	S-SW	SW	W-SW	W	W-NW	NW	N-NW	N	Nondirectional	K_d
(a) Frame 1																		
Section 1																		
50-year	53	57	55	62	68	70	68	70	73	70	66	60	56	51	58	62	94	0.78
500-year	95	97	94	108	110	107	111	113	123	133	134	111	107	91	126	111	141	0.95
Section 2																		
50-year	150	152	149	156	175	188	190	183	175	169	162	149	140	136	157	175	222	0.86
500-year	253	261	257	257	284	284	304	304	291	316	318	298	266	242	318	305	333	0.95
Section 3																		
50-year	40	42	39	41	48	52	50	46	48	45	44	37	33	34	41	47	61	0.86
500-year	68	73	68	70	78	77	87	85	80	86	87	74	70	60	80	77	91	0.95
Section 4																		
50-year	3	3	3	3	4	4	3	2	1	1	1	1	1	2	3	3	5	0.75
500-year	6	6	5	6	7	7	7	6	6	5	4	4	4	5	7	6	8	0.95
Section 5																		
50-year	36	40	42	41	43	47	53	50	47	46	44	42	38	34	37	43	61	0.88
500-year	65	70	77	70	72	75	80	89	87	82	84	85	71	74	87	82	91	0.98
Section 6																		
50-year	137	143	154	157	168	178	194	187	176	172	164	153	144	134	148	162	222	0.87
500-year	257	257	280	251	264	279	305	326	317	298	294	297	272	260	313	311	333	0.98
(b) Frame 2																		
Section 1																		
50-year	60	61	67	75	72	70	77	86	82	71	63	57	58	60	66	68	110	0.78
500-year	115	111	127	121	126	131	128	144	157	157	131	126	102	117	125	138	166	0.95
Section 2																		
50-year	161	163	176	196	197	202	207	215	210	194	174	150	146	150	177	186	277	0.78
500-year	288	292	318	324	324	346	347	363	394	395	328	318	265	293	365	351	416	0.95
Section 3																		
50-year	50	46	49	53	58	64	63	60	54	52	44	37	37	40	52	57	80	0.80
500-year	88	92	92	92	104	108	106	113	114	100	94	84	85	79	116	109	120	0.97
Section 4																		
50-year	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	0.95
500-year	5	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	0.97
Section 5																		
50-year	37	43	50	53	51	50	55	63	64	63	56	51	48	41	44	44	80	0.80
500-year	78	83	84	92	93	92	99	109	105	113	114	106	99	83	119	96	120	0.99
Section 6																		
50-year	150	163	181	188	184	182	207	224	219	195	185	172	155	154	173	174	277	0.81
500-year	288	279	318	319	318	329	376	363	394	395	350	323	286	293	325	334	416	0.95
(c) Frame 5																		
Section 1																		
50-year	44	42	46	51	49	48	50	45	39	38	44	49	52	48	48	47	64	0.80
500-year	77	76	75	84	91	92	81	74	67	70	80	77	86	84	79	75	97	0.95
Section 2																		
50-year	118	110	120	130	126	121	122	108	98	93	103	118	125	117	118	121	166	0.78
500-year	197	197	193	217	236	236	196	190	161	176	185	188	203	196	192	194	249	0.95
Section 3																		
50-year	23	20	19	20	23	26	28	28	27	28	32	35	34	30	26	25	45	0.78
500-year	42	47	44	43	46	45	51	49	50	46	58	58	63	63	54	51	67	0.95
Section 4																		
50-year	0	0	1	0	0	0	1	1	1	1	0	−2	−2	−2	−2	0	1	0.75
500-year	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.95
Section 5																		
50-year	30	29	32	34	32	30	26	20	19	19	21	23	24	26	25	29	45	0.76
500-year	51	53	53	58	63	63	53	51	42	44	43	45	46	45	51	49	67	0.95
Section 6																		
50-year	105	100	105	112	117	122	121	119	104	104	122	131	131	123	117	111	166	0.79
500-year	163	193	185	186	199	196	192	194	190	170	204	217	236	236	196	189	249	0.95

bending moments induced by each of the 16 directional wind speeds in each of the 999 hurricanes. For each hurricane and for each of these 16 directions, these bending moments are proportional to the respective largest directional influence factor in the half-octant corresponding to the direction of interest, times the square of the wind speed blowing in that hurricane from that direction. (A higher resolution may be used but is not necessary for the purpose of estimating moments in frames.) For example, the moment $M_{ij}(\theta, n)$ induced at the cross section i of frame j by the wind speed $V(\theta, n)$ blowing from direction θ in hurricane n is

$$M_{ij}(\theta, n) = V^2(\theta, n)m_{ij}(\theta)$$

where $m_{ij}(\theta)$ = moment influence directional factor. For each hurricane, one of the 16 directional speeds produces the maximum bending moment at the cross section being considered. In this manner, 999 largest bending moments at each cross section and for each frame are obtained. The rate of arrival of hurricanes at the assumed building locations being η/year, it follows that the mth highest of the 999 calculated bending moments is an estimator of the moment with a $[999/(m\eta)]$-year mean recurrence interval. For example, if, as is the case near Miami, the rate of arrival of hurricanes at the site of concern is 0.5/year, the 4th highest moment and the 40th highest moments are estimators of the moments with a 500-year and a 50-year mean recurrence interval, respectively. Calculations were performed for each of 16 distinct building orientations, i.e., for the cases where the long building axis is in the N, NNE, NE, . . . NNW direction.

Calculations That Do Not Take Wind Directionality into Account

The calculation sequence proceeds as follows. Instead of multiplying, for each hurricane, the 16 directional influence factors by the squares of the respective directional speeds, the program multiplies the largest of the 16 directional influence factors by the square of the largest wind speed in that hurricane, regardless of that speed's direction. Thus, 999 bending moments are obtained. The mth highest bending moment is an estimator of the bending moment with a nominal $[999/(m\eta)]$-year mean recurrence interval, calculated by disregarding the effect of wind directionality. It is emphasized that the nominal mean recurrence interval differs from the actual mean recurrence interval estimated by considering the wind loading phenomenon in a physically realistic fashion, that is, by taking into account correctly the effect of wind directionality.

RESULTS

Typical results are shown in Table 1 for a coastal location near Miami, FL. The results pertain to three frames (frames 1, 2, and 5; see Fig. 2) and to six cross sections of those frames (Fig. 1). The results consist of wind-induced moments with nominal 50-year and 500-year mean recurrence intervals estimated by disregarding wind directionality effects (column 17 of Table 1), and wind-induced moments with 50-year and 500-year mean recurrence intervals estimated by taking wind directionality effects into account for buildings whose axis parallel to the long dimension is oriented in the NNE, NE, . . . , NW, and N direction (columns 1–16).

As an example, we consider cross section 2 (the column cross section at the column knee) of frame 1. The directional influence coefficient for moments at this cross section is shown in Fig. 3, and the estimated wind speeds with a 50-year and 500-year mean recurrence interval are shown in Fig. 4. (For some directions the winds induced by most, though not all, hurricanes are zero, owing to the directions at the site of interest of the velocities associated with the respective vortex flows; for example, if a hurricane with a northwestward translation velocity hits a site located on the hurricane translation axis, the velocity into the southeast direction will be zero. For those directions, the estimated 50-year wind speed—which, as was shown earlier, corresponds in our case to the 40th highest speed in a set of 999 wind speeds—will be zero, but the estimated 500-year speed will not be zero; see Fig. 4. This would also be true if a set of size larger than 999 were used.) For none of the 16 building orientations does the moment with a 50-year mean recurrence interval (columns 1–16) exceed 86% of the moment estimated without accounting for wind directionality (column 17). Therefore, in this case a 0.85 directionality reduction factor adequately reflects the wind directionality effect.

Let us now consider the estimated 500-year moments. The 500-year moment calculated without considering wind directionality effects is 333 kN-m. The use of the 0.85 factor specified by the ASCE 7-98 Standard to obtain the value corresponding to strength design yields 283 kN-m. The 283 kN moment is exceeded for buildings with SSE, S, SSW, SW, WSW, W, NNW, and N orientation. Therefore, according to the results of Table 1, the use of the ASCE 7-98 blanket di-

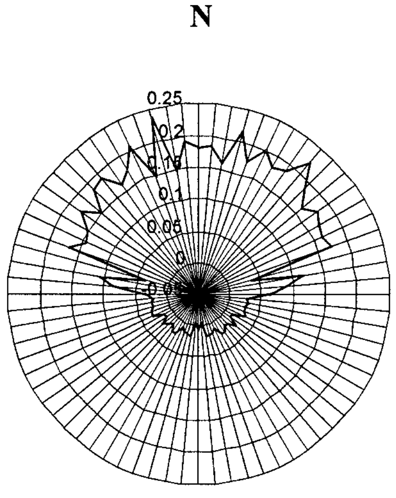

FIG. 3. Directional Influence Factor for Moment at Cross Section 2 of Frame 1 [i.e., Moment $m_{21}(\theta)$ Induced by Winds with 1 m/s Speed at 10 m above Ground in Open Terrain Blowing from Directions θ], in kN/m

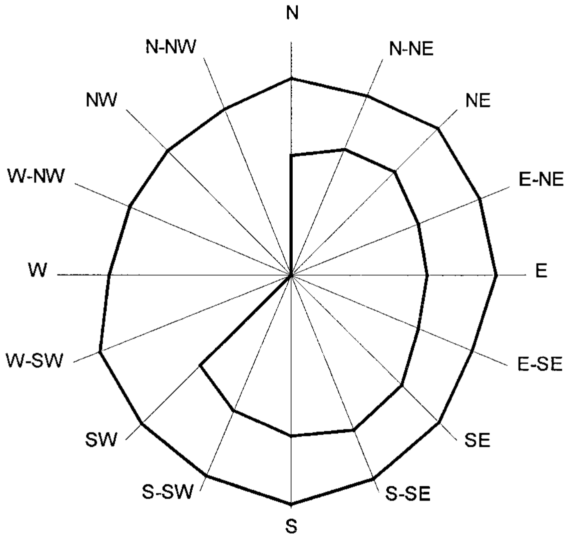

FIG. 4. Estimated Wind Speeds with 50-year and 500-year Mean Recurrence Intervals, in m/s, at Coastal Location near Miami, FL, as Functions of Direction θ; Maximum Estimated 500-year Speed Is 36.5 m/s (from South Direction)

rectionality reduction factor would lead to underestimation of the 500-year moments by a significant percentage of the total number of buildings at or near milestone 1100. Although the results depend on the directional characteristics of the wind climate and therefore differ from milepost to milepost, results similar to those of Table 1 were consistently obtained for other locations along the Gulf and Atlantic Coasts (Rigato 1999).

The writers also note that our results confirm the finding in Simiu and Heckert (1998) that wind directionality reduction factors depend upon mean recurrence interval. This dependence is not reflected in the ASCE 7-98 provisions, which apply the same reduction factor for winds with nominal 50-yr and 500-yr mean recurrence intervals. For the example considered in the preceding paragraph, the ratio of the largest moment estimated by taking wind directionality into account to the moment estimated by disregarding wind directionality is 0.86 for moments with a 50-year mean recurrence interval and 0.95 for moments with a 500-year mean recurrence interval (column 18). The writers ascribe the increase of the wind directionality reduction factor with mean recurrence interval to the greater chance that a directionally unfavorable intense wind would affect the structure in, say, 2,000 years than in, say, 25 years. Mathematically it would be of interest to investigate this problem by using a bivariate probabilistic model in which one of the variates is the wind speed and the other variate is the wind direction. However, to the writers' knowledge, in the present state of the art the probabilistic apparatus needed for such an investigation is not available. This is one of the motivations for the univariate approach used in this work.

CONCLUSIONS

From the results presented in this paper, the writers conclude the following:

1. Database-assisted design makes it possible to account for wind direction in a manner that yields more risk-consistent designs than can be achieved by using conventional standard provisions for wind loads. This is the case for buildings whose orientation is not known at the time of their design and is true to an even greater extend for buildings with known orientation.
2. For buildings with either known or unknown orientation, database-assisted design provisions allow the option of differentiated designs of distinct frames within a building.
3. The use of the blanket wind direction reduction factor $K_d = 0.85$ specified for buildings in the ASCE 7-98 Standard may result, for as many as 10 or even 15% of the buildings designed in accordance with the standard, in the significant underestimation of wind effects corresponding to strength design. Since a similar wind reduction factor is implicit in earlier versions of the ASCE 7 Standard, the same statement holds for buildings designed in accordance with those versions. It may be argued that the term ''wind directionality factor'' applied to the 0.85 reduction factor in the ASCE 7-98 Standard is a misnomer, and that this factor in fact makes allowance for other, nonspecified effects. The writers believe our analysis will allow a separation of those other effects, if they exist, leading to more realistic standard provisions.

APPENDIX I. DEPENDENCE OF DIRECTIONALITY REDUCTION FACTOR ON MEAN RECURRENCE INTERVAL OF WIND SPEEDS

To understand qualitatively the dependence of the wind directionality reduction factor upon mean recurrence interval, consider the simple case of pressure at a point and assume that the wind climate is defined by extreme yearly wind speeds blowing from N directions. The pressures depend on wind speed and direction in the form

$$p(\theta) = (\rho/2)C(\theta)x(\theta)^2 \tag{1}$$

where ρ = air density; C = aerodynamic pressure or force coefficient (or other wind effect coefficient independent of wind speed); p = pressure or force (or other wind effect); x = maximum yearly wind speed; and θ = wind direction, respectively. We may base our estimates of extreme wind effects on the N directional time series

$$P_j(\theta_i) = C(\theta_i)x_j(\theta_i)^2/\max_i[C(\theta_i)] \tag{2}$$

where $i = 1, 2, \ldots, N$ denotes the wind direction; $j = 1, 2, \ldots, M$; M = number of years of record; $\max_i[C(\theta_i)]$ = largest of the values $C(\theta_i)$; and $\max_i$ denotes the maximum over all is. From these time series we form the single time series

$$P_j = \max_i\{[P_j(\theta_i)]\} \tag{3a}$$

To within a constant factor, P_j is the largest wind pressure in a year j. Rather than analyzing the time series P_j, we analyze the time series of equivalent wind speeds

$$x_{eq,j} = P_j^{1/2} \tag{3b}$$

The analysis yields the extreme values $x_{eq,R}$ where R denotes the mean recurrence interval (MRI). The extreme wind effect for the MRI of interest is

$$p_R = (\rho/2)\{\max_i[C(\theta_i)]\}(x_{eq,R})^2 \tag{4}$$

We now discuss estimates that do not account for wind directionality. First, form the time series

$$x_j^{\max} = \max_i[x_j(\theta_i)] \tag{5}$$

of the largest wind speed in year j, regardless of its direction. Next, from the analysis of this time series, obtain the estimate x_R; that is, the nondirectional estimate of the R-yr speed, where R now denotes a nominal MRI. The corresponding nondirectional estimate of the wind effect with an R-yr nominal MRI is

$$p_{R,\mathrm{nom}} = (\rho/2)\max_i[C(\theta_i)]x_R^2 \tag{6}$$

In other words, $p_{R,\mathrm{nom}}$ is obtained by following exactly the same steps used when accounting for wind directionality to estimate p_R, except that in (2), the factor $C(\theta_i)$ is replaced by the factor $\max_i[C(\theta_i)]$. Each of the terms of the time series $x_j^{\max}$ is equal to or larger than its counterpart in the time series $x_{eq,j}$. Therefore, if the MRI and the nominal MRI have the same value, one might expect $p_R < p_{R,\mathrm{nom}}$.

We now consider, as a deliberately simple illustration, the wind speed time series $x_j(\theta_i)$ ($i = 1, 2$; $j = 1, 2, 3$): $x_j(\theta_1) = \{52, 41, 47\}$, and $x_j(\theta_2) = \{48, 46, 39\}$. Let us assume that the directional pressure coefficients are $C(\theta_1) = 0.5$ and $C(\theta_2) = 1$. Given these values of $C(\theta_j)$, it follows from (3) that the time series of the equivalent wind speeds $x_{eq,j}$ is identical to the time series $x_j(\theta_2)$. Its mean and standard deviation are 44.33 and 4.726, respectively. On the other hand, using (5), we obtain the time series $x_j^{\max} = \{52, 46, 47\}$, with mean and standard deviation $48.33 > 44.33$ and $3.215 < 4.726$, respectively. From the fact that the mean is larger and the standard deviation is smaller for the time series $x_j^{\max}$ than for the time series $x_{eq,j}$, and from typical expressions of percentage points as functions of population means and standard deviations, it follows that, for very short MRIs, x_R can be significantly larger than x_{Req}, while for very long MRIs this is no longer the case. Since designs are governed by loads with large MRIs, rather than by the 50-yr loads, this result indicates that ultimate loads obtained by the nondirectional method (i.e., from the time series $x_j^{\max}$) may be only marginally conservative. We note, however, that, as indicated by tens of computer runs, for long mean recurrence intervals the directional reduction factor, while being on average larger than 0.85, is less than unity, typically 0.95 or so.

The example presented in this Appendix was deliberately simple, but the reader can consider actual directional sets, either for hurricane or nonhurricane winds, that can be accessed as indicated in Appendix 2.

APPENDIX II. INSTRUCTIONS FOR ACCESSING COMPUTER PROGRAMS AND WIND SPEED DATA FILES

If you are using the MicroSoft Windows FTP program, use the following commands:

First, create a new folder called ASCE-7 or a name of your choice.

You should create subdirectories named ''maxyear,'' ''directional,'' and ''hurricane.''

You will also need subdirectories below each of these named ''programs'' and ''datasets.''

This can be done from the Window Explorer program.

Click the START button on the task bar.

Click once on the RUN menu option.

Enter the command: ftp ftp.nist.gov ⟨cr⟩ or click on OK.

A black MS/DOS window will open and you will be prompted for a username and then a password.

ftp> User: anonymous

ftp> Password: (enter your full email address)

ftp> lcd c:\ASCE-7 (or the directory you created above)

ftp> cd /pub/bfrl/emil (this is the main directory)

ftp> dir (You should see the subdirectories ''maxyear,'' ''directional,'' and ''hurricane.'')

Each directory contains a readme file, programs, and datasets.

For example, to access the readme file for the hurricane directory set the default to the hurricane directory:

ftp> cd hurricane (Do not use a ''/'' here because you only want to go to the next lower directory.)

ftp> dir (You should be able to see the readme file in the directory listing.)

To actually read the contents you will need to download this file and then open it on your local computer with a word processor program. To download the file, use the following commands:

ftp> lcd hurricane (This will place the file in the correct local directory ''c:\ASCE-7\hurricane.'')

ftp> asc (The file will be transferred as an ASCII text file —this is usually the default mode.)

ftp> get readme (The file will be transferred to a file called readme in the current local directory.)

To return to the main directory you can use the command ''cd ..'' or ''cd /pub/bfrl/emil.''

Likewise, you will need to change your local directory to download the other readme file.

You may choose to save the readme files to a different name, such as: get readme hurricane.txt.

To download the programs and data sets you should either use the full path names or set the default directories for the local and remote computers to the corresponding directories.

The command to move multiple files between ''default'' directories is:

ftp> mget *.*

Other FTP programs for Windows offer dual directory displays for the local and remote systems, with click and drag capabilities for downloading both individual files and entire folders (directories). Anyone not familiar with command line FTP programs may find this process to be easier with one of these programs.

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