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Statistical evaluation of the wind loads as proposed by the Turkish standard TS 498

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Wind Load, Statistics, Uncertainties, TS 498.

ABSTRACT

In this study, wind loads resulting from wind speeds are examined by using statistical methods. For this purpose, the wind speed data are collected from different regions of Turkey. In addition to these data, the published data and information in the international literature are also taken into account in comparing the wind load statistics. The ratios of mean to nominal load values are determined for calibration purposes. While the mean values of wind loads are computed by considering the underlying uncertainties, the nominal values of wind loads are taken directly from the Turkish standard TS 498 (Design Loads for Buildings). Although some of the loads acting on a structure, such as dead and live loads are independent of the geographical location of the structure, environmental loads like wind load are highly dependent on the regional location of the structure. In order to determine the wind load statistics to represent the whole Turkey, it is required to select some reference regions. In this study, eleven regions are chosen. At the end of the analyses, it is observed that although in some regions the values given in TS 498 are sufficient, they are overestimated in some other regions. In addition, it is necessary that the calculation method of the wind load proposed by TS 498 should be revised and also the nominal values of wind loads should be modified.

Türk standardı TS 498'de önerilen rüzgâr yüklerinin istatistiksel olarak değerlendirilmesi

Anahtar Kelimeler
Rüzgar Yükü, İstatistik, Belirsizlik, TS 498

ÖZET

Bu çalışmada, rüzgar hızından elde edilen rüzgar yükleri istatistiksel yöntemler kullanılarak incelenmiştir. Bu amaçla Türkiye'nin değişik şehirleri için rüzgar hızı verileri toplanmıştır. Bu verilere ilaveten uluslararası kaynaklardan elde edilen veri ve bilgiler de rüzgar yükü istatistiksel değerlerinin belirlenmesinde kullanılmıştır. Kalibrasyon amacıyla, "gerçek" ortalama değerlerin ilgili standartlarda önerilen nominal değerlere oranı hesaplanmıştır. Rüzgar yükünün "gerçek" ortalama değerleri bazı belirsizlik kaynaklarının da dikkate alınmasıyla hesaplanırken, rüzgar yükünün nominal değerleri doğrudan Türk standardı TS 498'den (Yapı Elemanlarının Boyutlandırılmasında Alınacak Yüklerin Hesap Değerleri) alınmıştır. Ölü ve hareketli yükler gibi bazı yükler yapının içerisinde bulunduğu coğrafyadan bağımsız olmalarına rağmen, rüzgâr yükü gibi çevresel yükler yapının coğrafi bölgesine oldukça bağımlıdır. Bundan dolayı bütün Türkiye'yi yansıtması beklenen rüzgâr yükü istatistiksel değerlerinin hesaplanmasında bazı referans bölgelerin seçilmesi gerekmektedir. Bu çalışmada on bir şehir dikkate alınmıştır. Analizlerin sonucunda TS 498'de bazı şehirler için verilen değerlerin yeterli olduğu, bazı şehirler için verilen değerlerin ise aşırı yüksek olduğu sonucuna ulaşılmıştır. Bunlara ek olarak TS 498'de önerilen rüzgar yükü hesap yönteminin revize edilmesinin gerekli olduğu ve sıradan yapılar için verilen rüzgar yükü nominal değerlerinin değiştirilmesi gerektiği kanaatine varılmıştır.

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1. Introduction

In civil engineering, structural design codes specify minimum safety requirements and for this reason design specifications provide regular expressions for engineers in order to solve general practice oriented problems. For many years, the question of "how safe is safe enough" is asked by researchers applying safety theory to codified design. In order to find a considerable solution for this question, researchers are still working. There is always a probability of failure for structures. Accordingly, complete safety cannot be achieved. On the other hand, upgrading the safety level causes economical problems, therefore there must be a reasonable balance between safety and cost. In order to reach more meaningful design codes, code optimization based on total cost is necessary. An optimized load code means that recommended loads give the optimum solution for the expected designs. On the other hand, the determination of loads and load effects on the structures introduce a set of uncertainties. Here, the wind loads proposed by the Turkish Code TS 498 [1] are evaluated taking into consideration the associated uncertainties.

The assessment of wind load and reliability of structures under the wind loads has been receiving growing interest during the last few decades. However, a number of significant issues still remain unsolved [2]. Structural engineers should make certain that the structures subjected to wind load will be sufficient during its expected life with regard to both serviceability and structural safety. Accordingly, the information on the behavior of the structures under the wind action is required in order to realize the relation between the wind environment and the wind action [3].

Any type of structural load becomes meaningful if it leads to a load effect. Assuming a linear relationship between a load and its effect, the following formula gives the load effect, S_i, on the basis of its corresponding structural load, L_i [4,5]:

$$S_i = C_i N_i L_i \qquad (1)$$

where: S_i: load effect, C_i: influence coefficient, N_i: modeling parameter, L_i: structural load.

It should be noted that in this formula, the parameters on the right hand side of Eq.1, i.e. C_i, N_i, and L_i are assumed to be statistically independent. According to the FOSM method (First Order Second Moment Method), the mean and coefficient of variation for any load type can be computed from the following formulas, respectively:

$$\overline{S}_i = \overline{C}_i \overline{N}_i \overline{L}_i \qquad (2)$$

$$\Omega_{Si} = \sqrt{\Delta_{Ci}^2 + \Delta_{Ni}^2 + \Delta_{Li}^2} \qquad (3)$$

where: a bar (¯) over a random variable denotes the mean and Δ is the coefficient of variation. In the following sections, structural load effects resulting from the wind load will be evaluated. The published data in the literature and the local data compiled in Turkey will constitute the main sources of information in the evaluation of the wind load statistics. For calibration purposes, the ratio of mean to nominal load values will be determined. The nominal values of loads will be obtained from TS 498. It is to be noted that although the dead and live loads acting on a structure are independent of the geographical location of the structure, environmental loads, such as snow, wind and earthquake loads are highly dependent on the location of the structure. Accordingly, for the assessment of statistics of environmental loads, different cities, which will represent the whole Turkey, are chosen. In this selection, cities with the highest critical environmental loads are given priority. Also, cities with larger populations are preferred. Another criterion in this selection is that these cities are to be located in geographically different regions of Turkey. For the wind speed, data are obtained from the meteorological stations that are in the centers of these cities. The locations of these cities are shown in the following map.

2. Wind Load

Wind loads are derived by using the statistical data based on wind speed, mass density of air, pressure coefficient, parameters related to wind speed and exposure, and a gust factor that incorporates the effects of short gusts and the dynamic response of the structure. The wind load acting on a structure can be determined from the wind speed by using the standard hydrodynamic relationship, which can be rewritten for particular structures or surfaces of structures as follows [6]:

$$W = c.C_p.E_z.G.V^2 \qquad (4)$$

where: W: wind load, c: a constant related to mass density of air, C_p: pressure coefficient, E_z: exposure coefficient, G: gust factor, V: wind speed.The pressure factor, C_p, depends on the geometry and shape of the structure. It is the ratio of the pressure at relevant surface of the structure to the dynamic pressure of the wind [7]. The exposure coefficient, E_z, depends on the actual topographical conditions (e.g. urban area, enclosed valleys, slopes, hills, open country and also the presence of constructions near the structure). The gust factor is associated with the turbulence of the wind and the dynamic interaction between the structure and wind.

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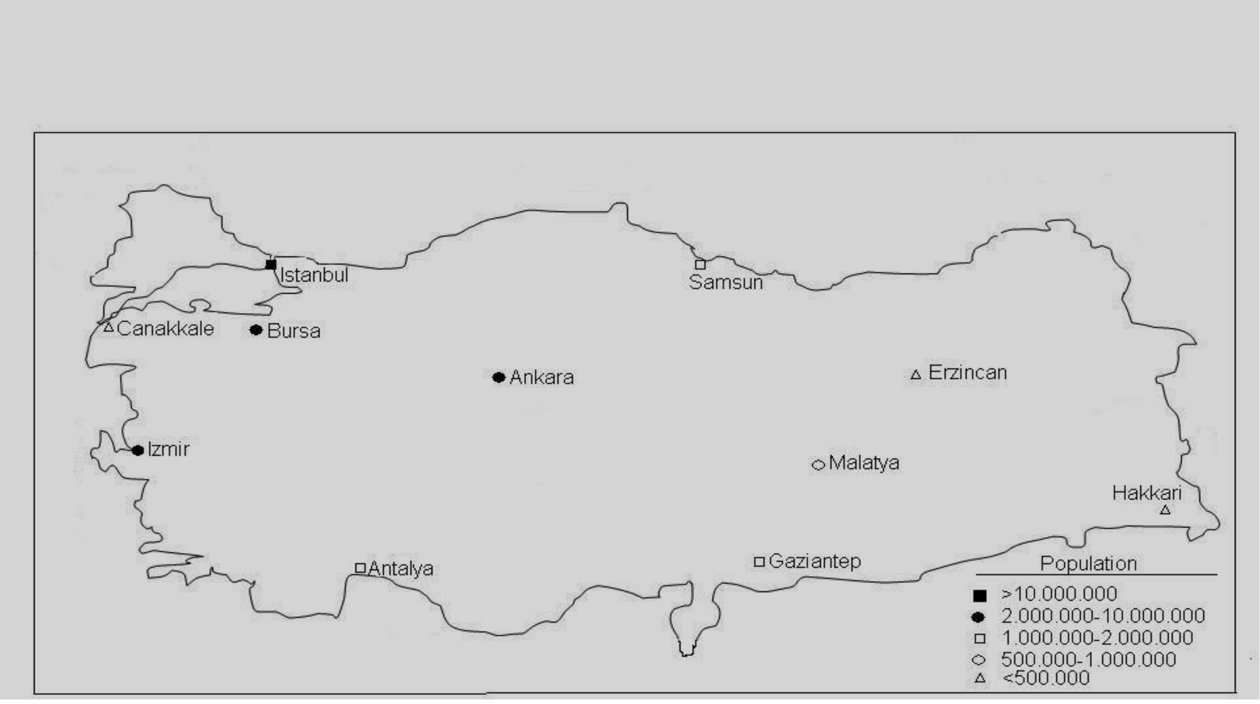

Figure 1 The map showing the locations of selected cities

Since the velocity parameter appears with its square in Eq. 4, it is a particularly important parameter in comparison with the other parameters. The overall uncertainty in wind load is also affected by uncertainties in the estimation of the pressure coefficient, the exposure factor and the gust factor.

2.1 Analysis of Wind Speed

Most of the statistical data available related to wind load are obtained from the monthly maximum or annual maximum wind speeds; the pressure coefficients and gust factors are consistent with this maximum wind speeds. The wind speed changes with latitude, longitude and altitude from the sea level and time [8]. In this study, since it is impractical to perform reliability analysis separately for each and every location where wind speed data is available, it is decided to collect this necessary data for twelve different locations in Turkey. Hence, Ankara, İzmir, Bursa, Antalya, Gaziantep, Samsun, Malatya, Erzincan, Çanakkale, Hakkari, Göztepe/İstanbul and Şile/İstanbul are selected in order to carry out the wind load analysis for Turkey. The required data on maximum yearly and maximum daily wind speeds are taken from the Turkish Meteorological Department (DMI). The wind speed is measured at 10 meters above the ground level in these locations [9].

The relevant statistical parameters are computed for the locations listed above. Type I and Type II extreme value distributions are the most common and appropriate probability distributions for wind speeds [4, 7]. Simiu and Scanlan [7] indicated that if the wind speed data are collected in locations where extraordinary wind speeds are very rare, the use of Type I distribution is more suitable as a probabilistic model. Fırat [3], Yücemen and Gülkan [10] and Kömürcü [11] used the Type I distribution for yearly maximum wind speed, daily maximum wind speed and lifetime maximum wind speed to describe the data that were recorded in Turkey. Because unusual winds are not seen frequently in Turkey, Type I distribution can be used to describe the wind speed data. Also the data analysis with BestFit and Minitab computer programs showed that Type I distribution fits data satisfactorily. For Lognormal, Normal, Extreme-value (Type I), Gamma, Weibull, Rayleigh probability distributions, the Chi-Square and Kolmogorov- Smirnov tests results, which were performed by using computer programs mentioned above, are given in Table 1. In this table, the p-value is a short form for probability value and is another way of saying the significance value. It refers to the probability of obtaining a test statistic at least as extreme as the one that was actually observed, assuming that the assumed distribution is true. In this study, daily maximum wind speed, V_{apt}, and annual maximum wind speed, V_{an}, will be used, which are respectively necessary for the calculation of the daily maximum wind and the yearly maximum wind loads. In addition to these two parameters, maximum wind speed, V_{50}, and nominal wind speed, V', are needed. V_{50}, which is the 50-year maximum wind speed, is derived from the annual maximum wind speed, V_{an}, and V' is obtained from TS

498. Since the data for the annual maximum wind speed fits the Type I distribution, maximum wind speed could also be described by a Type I distribution, and the mean value and the basic variability of the maximum wind speed are computed from the mean value and variability of V_{an} based on the following equations. Also, the prediction error due to insufficient sampling, Δ_1, is defined by using these computed values and inherent variability of annual maximum wind speed, $\delta_{V_{an}}$ according to Eq. 7 [4].

$$\overline{V}_{50} = \overline{V}_{an}\left(1 + \frac{\sqrt{6}}{\pi}\delta_{V_{an}} \ln 50\right) \tag{5}$$

$$\delta_{V_{50}} = \overline{V}_{an}\delta_{V_{an}} / \overline{V}_{50} \tag{6}$$

$$\Delta_1 = \frac{3.8\overline{V}_{an}\delta_{V_{an}}}{\left(\sqrt{n}\,\overline{V}_{50}\right)} \tag{7}$$

where: n is the sample size. It is to be noted that, as n increases, Δ_1 decreases. Dündar et al. [9] indicated that due to systematic errors and wrong calibration of devices associated with measurement of wind speed, an uncertainty of 0.05 should be included. In addition to the uncertainties involved in the recorded data, conversions including modeling, features of climatic parameters and roughness parameters of surface also create additional uncertainties. Therefore, an additional uncertainty of 0.02 is assumed to account for these factors [4, 11]. The mean values and variabilities of V_{apt}, V_{an} and V_{50} for Ankara, İzmir, Bursa, Antalya, Gaziantep, Samsun, Malatya, Erzincan, Çanakkale, Hakkari, Göztepe/İstanbul and Şile/İstanbul are presented in Table 2. Based on TS 498, the nominal wind speeds, V’, for these locations are also shown in Table 2.

2.2 Maximum, Yearly Maximum and Daily Maximum Wind Loads

As it is stated before, if the wind speed data are collected in locations where extraordinary wind speeds are very rare, the use of Type I distribution is more suitable as the probabilistic model; besides the data analysis with BestFit and Minitab computer programs showed that Type I distribution fits the data satisfactorily. Accordingly, Type I distribution is adopted as the probabilistic model for the wind speed data. On the other hand, the wind load may not have the same distribution of the wind speed. Ellingwood et al. [4] used Monte Carlo techniques assuming that C_p, E_z and G were described by normal distributions. As a result, it was found out that wind load, W, could be described by a Type I distribution over the range of the distribution above its 90th percentile. The parameters of the Type I largest extreme value distribution can be calculated through the following relationships [6]:

$$\alpha = \frac{\pi^2}{\sqrt{6}\sigma} \tag{8}$$

$$u = \mu - \frac{\gamma}{\alpha} \tag{9}$$

where, γ =0.577is the Euler’s constant.

Ellingwood et al. [4] and Kömürcü [11] estimated the mean values of the parameters C_p, E_z and G as 0.80, 1.61 and 0.45, respectively; and also quantified the variabilities of these parameters as 0.12, 0.11 and 0.16. These variability values are suitable for use in the code calibration related to wind load [6]. Ghiocel and Lungu [12] proposed the constant c to be equal to 0.0625, and Ellingwood et al. [4] quantified the variability of this parameter as 0.05. These values will also be used in this study for all of the locations considered. The mean and total variability of the maximum wind load are to be computed by utilizing FOSM method (Eqs. 2 and 3) yielding to the following equations

$$\overline{W} = c.\overline{C}_p.\overline{E}_z.\overline{G}.\overline{V}^2 \tag{10}$$

$$\Omega_W = \sqrt{\Omega_C{}^2 + \Omega_{C_p}{}^2 + \Omega_G{}^2 + \Omega_{E_z}{}^2 + 2\Omega_{V_{50}}{}^2} \tag{11}$$

The statistics related to the yearly maximum wind load, W_{an}, and daily maximum wind load, W_{apt}, can be calculated in a similar way. The mean values and total uncertainties of the maximum, yearly maximum and daily maximum wind loads for relevant locations are presented in Table 3. In addition, mean to nominal wind load ratios are shown in Table 4.

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Table 1. The Chi-Square (χ^2) and Kolmogorov- Smirnov (K-S) test results for the annual wind speeds recorded at different locations in Turkey

Annual wind speed							
Prob. Dist.	**Test**			**Prob. Dist.**	**Test**		
	χ^2	**p-value**	**K-S**		χ^2	**p-value**	**K-S**
	Ankara				Malatya		
Ext. value	8.957	0.2558	0.5953	Normal	9.333	0.3150	0.1013
Normal	9.304	0.2315	0.1244	Weibull	9.333	0.3150	0.1074
Rayleigh	10.00	0.1886	0.8595	Rayleigh	13.67	0.0909	0.1541
Weibull	11.74	0.1095	0.4555	Ext. value	17.00	0.0301	0.1587
Lognormal	12.93	0.0871	0.4513		Erzincan		
	İzmir			Lognormal	12.43	0.0871	0.1496
Normal	4.080	0.7705	0.0929	Ext. value	13.48	0.0613	0.1617
Weibull	4.080	0.7705	0.0884	Gamma	12.43	0.0871	0.1641
Ext value	7.600	0.3692	0.1296	Weibull	16.26	0.0228	0.1607
	Bursa			Rayleigh	23.91	0.0012	0.1999
Ext value	5.478	0.6018	0.0935	Normal	32.96	2.7x10-5	0.2149
Rayleigh	2.696	0.9117	0.0988		Çanakkale		
Weibull	2.696	0.9117	0.1014	Normal	4.667	0.7925	0.0919
Lognormal	4.087	0.7697	0.1030	Weibull	7.00	0.5366	0.0682
Normal	5.478	0.6018	0.0997	Ext. value	19.33	0.0132	0.1512
	Antalya				Hakkari		
Lognormal	3.408	0.8449	0.0949	Ext. value	4.814	0.6827	0.0872
Weibull	3.408	0.8449	0.0727	Lognormal	4.442	0.7277	0.1220
Rayleigh	4.714	0.6948	0.1273	Normal	4.442	0.7277	0.1229
Ext value	6.020	0.5374	0.1010	Rayleigh	8.163	0.3185	0.0853
	Gaziantep				Göztepe/İstanbul		
Ext. value	9.612	0.2116	0.0869	Normal	15.62	0.0288	0.1607
Weibull	8.306	0.3064	0.0971	Ext. value	21.67	0.0029	0.2070
Rayleigh	8.633	0.2801	0.1160		Şile/İstanbul		
Lognormal	9.939	0.1921	0.0870	Ext. value	7.059	0.5303	0.0761
Normal	10.92	0.1422	0.1484	Weibull	11.65	0.16.77	0.0969
	Samsun			Normal	14.47	0.0703	0.0990
Normal	9.333	0.3150	0.1074	Gamma	15.18	0.0558	0.0815
Rayleigh	13.67	0.0909	0.1541	Lognormal	15.18	0.0558	0.0808
Ext. value	17.00	0.0301	0.1587				

Note 1: At the significance level α=5%, 1-α percentile value of the Chi-Square test, $\chi^2_{0.955}$=11.1 for Ankara, İzmir, Bursa, Antalya, Gaziantep, Erzincan, Hakkari and Göztepe; and $\chi^2_{0.955}$=12.6 for Samsun, Malatya, Şile and Bursa.

Note 2: The critical value of K-S test at the 5% significance level is: $D_{50}^{0.05}$ =0.19.

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Table 2 Mean values and coefficients of variation of wind speeds for different locations

Location	**Parameter**								
	$\overline{V}_{apt}$ **(m/s)**	$\Omega_{V_{apt}}$	$\overline{V}_{an}$ **(m/s)**	$\Omega_{V_{an}}$	$\overline{V}_{50}$ **(m/s)**	$\delta_{V_{50}}$	Δ_1	$\Omega_{V_{50}}$	V' **(m/s)**
Ankara	8.50	0.33	20.13	0.24	34.25	0.135	0.045	0.15	36
İzmir	12.45	0.29	26.19	0.14	36.58	0.093	0.036	0.11	36
Bursa	6.53	0.44	23.92	0.21	38.51	0.124	0.043	0.14	36
Antalya	10.23	0.47	26.62	0.21	42.83	0.124	0.042	0.14	36
Gaziantep	5.49	0.44	17.53	0.25	30.63	0.139	0.043	0.16	36
Samsun	8.06	0.53	23.11	0.24	39.23	0.135	0.040	0.15	36
Malatya	6.52	0.54	15.09	0.46	36.26	0.191	0.041	0.20	36
Erzincan	6.65	0.44	19.07	0.29	35.94	0.154	0.046	0.17	36
Çanakkale	11.14	0.41	28.99	0.18	44.02	0.112	0.038	0.13	36
Hakkari	7. 07	0.54	20.19	0.22	33.12	0.128	0.045	0.15	36
Göztepe/İstanbul	6.95	0.53	19.67	0.30	37.67	0.157	0.046	0.17	36
Şile/ İstanbul	8.72	0.46	25.21	0.29	46.74	0.151	0.043	0.17	36

Table 3 Mean values and the total uncertainties of wind loads for different locations in Turkey

Location	**Parameter**						
	$\overline{W}_{apt}$ **(kN/m^2)**	$\overline{W}_{an}$ **(kN/m^2)**	$\overline{W}$ **(kN/m^2)**	W' **(kN/m^2)**	$\Omega_{W_{apt}}$	$\Omega_{W_{an}}$	Ω_W
Ankara	0.056	0.147	0.425	0.96	0.52	0.41	0.32
İzmir	0.015	0.248	0.485	0.96	0.47	0.31	0.28
Bursa	0.038	0.207	0.537	0.96	0.67	0.38	0.31
Antalya	0.011	0.257	0.665	0.96	0.71	0.38	0.31
Gaziantep	0.011	0.111	0.34	0.96	0.66	0.42	0.33
Samsun	0.024	0.193	0.558	0.96	0.79	0.41	0.32
Malatya	0.015	0.082	0.476	0.96	0.80	0.69	0.37
Erzincan	0.016	0.132	0.468	0.96	0.67	0.47	0.34
Çanakkale	0.045	0.304	0.702	0.96	0.63	0.35	0.30
Hakkari	0.018	0.148	0.397	0.96	0.80	0.39	0.32
Göztepe/İstanbul	0.017	0.14	0.514	0.96	0.40	0.48	0.34
Şile/ İstanbul	0.028	0.23	0.791	0.96	0.70	0.47	0.34

3. Conclusions

In this study, wind loads are analyzed by using statistical methods. To accomplish this purpose, the wind speed data are collected from different regions of Turkey. After conducting a set of statistical analyses on wind speed data, the mean values of wind loads are computed by taking into consideration the different uncertainty sources. In addition to the computed values, the published data and information available in the foreign literature are taken into consideration in comparing the wind load statistics. The nominal values of wind loads are directly taken from the Turkish Standard TS 498. The ratios of mean to nominal load values are computed for the purpose of comparing the geographically varying wind loads. For the cities considered in this study, the mean to nominal ratios range from 0.09 to 0.32 for arbitrary point-in-time wind load and also from 0.35 to 0.82 for maximum wind load. As it is seen from these values, the nominal wind load values in TS 498 stay on the safe side for all locations. However, the wind load values proposed by TS 498 are overestimated in some regions. The total uncertainties in arbitrary point-in-time wind loads according to the cities considered in this study are observed to vary from 0.60 to 0.93. In addition, the total uncertainties in maximum wind loads change within a range of 0.27 and 0.48. These uncertainty values indicate that the variabilities in the wind load are very high. It is also noted that arbitrary point-in-time wind loads show significantly more variation than the maximum wind loads. Besides, wind load shows variability in the different areas of a city; in other words, the wind load effect on a structure located in a valley is not the same on a structure located on a hill side due to different wind speeds. Therefore, for special areas and structures, the data on daily maximum wind speeds and annual maximum wind speeds can be recorded; then the method proposed in this study can be used in order to determine the more appropriate wind loads.

Table 4 Mean to nominal wind load ratios and associated total uncertainties for different locations

Location	Parameter					
	$\overline{W}_{apt} / W'$ (kN/m^2)	$\Omega_{W\,apt}$	$\overline{W}_{an} / W'$ (kN/m^2)	$\Omega_{W\,an}$	$\overline{W} / W'$ (kN/m^2)	Ω_W
Ankara	0.058	0.52	0.153	0.41	0.443	0.32
İzmir	0.016	0.47	0.258	0.31	0.505	0.28
Bursa	0.040	0.67	0.216	0.38	0.559	0.31
Antalya	0.011	0.71	0.268	0.38	0.693	0.31
Gaziantep	0.011	0.66	0.116	0.42	0.354	0.33
Samsun	0.025	0.79	0.201	0.41	0.581	0.32
Malatya	0.016	0.80	0.085	0.69	0.496	0.37
Erzincan	0.017	0.67	0.138	0.47	0.488	0.34
Çanakkale	0.047	0.63	0.317	0.35	0.731	0.30
Hakkari	0.019	0.80	0.154	0.39	0.414	0.32
Göztepe/İstanbul	0.018	0.40	0.146	0.48	0.535	0.34
Şile/ İstanbul	0.029	0.70	0.240	0.47	0.824	0.34

References

1. Türk Standartları, Yapı Elemanlarının Boyutlandırılmasında Alınacak Yüklerin Hesap Değerleri (TS 498), Türk Standartları Enstitüsü , Ankara, 1997.
2. Minciarelli, F., Gioffre, M., Grigoriu, M. and Simiu, E., Estimates of Extreme Wind Effects and Wind Load Factors: Influence of Knowledge Uncertainties, Probabilistic Engineering Mechanics, Vol. 16, pp 331-340, 2001.
3. Fırat F.K., Development of Load and Resistance Factors for Reinforced Concrete Structures in Turkey, The Graduate School of Natural and Applied Sciences, Middle East Technical University, Doctorate Thesis, Ankara, 2007.
4. Ellingwood, B.R., Galambos, T.V., MacGregor, J.G. and Cornell, C.A., Development of a Probability Based Load Criterion for American National Standards A58, NPS Special Publication 577, 1980.
5. Fırat, F.K., TS 498'de Önerilen Çatı Kar Yüklerinin İstatistiksel Yöntemlerle Hesaplanan Çatı Kar Yükleriyle Karşılaştırılması, Fırat Üniversitesi, Mühendislik Bilimleri Dergisi, Cilt:21, Sayı:2, 115-123, 2009.
6. Melchers R.E., Structural Reliability Analysis and Prediction, John Wiley & Sons, Inc., Chichester, England, 2002.
7. Simiu E. and Scalan, R.H., Wind Effects on Structures, 1st ed., John Wiley, New York, 1978.
8. Şahin, A.D., Türkiye Rüzgarlarının Alan Zaman Modellemesi, Ph. D. Thesis, İTÜ, İstanbul, 2001.
9. Dündar C., Türkiye Rüzgar Atlası, T.C. Başbakanlık Devlet Meteoroloji Genel Müdürlüğü ve Enerji Tabii Kaynaklar Bakanlığı Elektrik İsleri Etüt İdaresi Genel Müdürlüğü, Ankara, 2002.
10. Yücemen, M.S. and Gülkan, P., Betonarme Yapılar İçin Yük ve Dayanım Katsayılarının Belirlenmesi, 10. Teknik Kongre, Cilt 2, İnşaat Mühendisleri Odası, s. 637-651, 1989.
11. Kömürcü, A.M., A Probabilistic Assessment of Load and Resistance Factors for Reinforced Concrete Structures Considering the Design Practice in Turkey, M. Sc. Thesis, Department of Civil Engineering, METU, Ankara, 1995.
12. Ghiocel, D. and Lungu, D., Wind, Snow and Temperature Effects on Structures Based On Probability, Abacus Press, Turbridge Wells, Kent, 1974.