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TULTECH

Fundamental Basic Wind Speed in Albania: An Adoption in Accordance with Eurocodes

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Abstract
Non-EU states are in the process of adopting and implementing Eurocodes as design standards. The majority of Eurocodes have been translated in Albania, however, their National Annexes are incomplete. Fundamental basic wind velocity is one of the topics in the Eurocodes for structural design, and this study presents a method for calculating it, based on available wind velocity data as well as past studies and technical design codes. Existing wind speed maps with a 2 percent chance of exceedance (PoE) have insufficient information about wind speed duration, orography, and the data they were derived from, as well as other references. A correlation must be conducted in order to utilise current maps, studies, and wind data in compliance with Eurocodes. The purpose of this work is to investigate the nature of the data included in existing wind maps and other available wind velocity sources, as well as to construct a fundamental wind speed map of Albania compliant with Eurocodes.

Keywords: *Fundamental Basic Wind Velocity, Albanian Wind Map, Probability of Exceedance, Wind Speed Duration*

INTRODUCTION

In Albania, most of the engineers already use Eurocodes for structural design [1]. Determining the loads, especially dynamic ones, and their combinations is essential during the design process [2-8]. Wind load accuracy is directly related to the structural safety of the construction works. The high demand for tall buildings, light structures and structures where orography has a considerable effect, makes wind load even more critical in the design process.

KTP's – Albanian technical design codes in force – does not give a detailed description how the existing wind zones map is defined, i.e. the data used for maximum wind velocity, fundamental basic wind velocity, Probability of Exceedance - PoE, etc. Moreover, the wind map given in the national technical design code [9, 10] follow a different approach from Eurocodes.

Referring to [1], the characteristic value of wind action, like other climatic actions, is based upon the PoE equal to 0,02 (2% fractile) within one-year period and differs from other characteristic value of variable actions (5% fractile). By definition, fundamental basic wind velocity is the 10 min mean wind velocity with 2% PoE within one year, irrespective of wind direction, at a height of 10 m above flat open terrain. The Existing data for the wind speed in Albania gives only few information about wind measurements, wind speed duration, orography and terrain height.

This research work aims to develop a preliminary map of wind speed which can be used when designing in accordance with Eurocodes. This draft map is advised to be used as transition map until a final wind map based on more reliable data measurements is developed.

BACKGROUND INFORMATION

The data used in this research work are shortly described hereunder, in order to make it more comprehensible and helpful for later research, when more accurate data will be available. Some of the data analysed were not found in any of the digital formats, hence, gathering the hard copies of the old original data has not been so easy.

Wind speed and pressure zones map still in force

The technical design code, KTP-7-78 [9], still in force in Albania, defines how wind pressure on structures shall be calculated. It starts by giving wind zones map which sets basic wind speed and wind pressure for all territory, followed by wind load coefficients and formulas to be used for structural calculations. As it is shown in Figure 1 and parameters of equation (1), the Albanian territory is divided into two main wind zones.

$$\left.\begin{array}{llll} KTP\,Zone\ I & V_I = 25\ m/s & P_{0,I} = 40\ kg/m^2 \\ KTP\,Zone\ II & V_{II} = 31\ m/s & P_{0,II} = 60\ kg/m^2 \end{array}\right\} \quad (1)$$

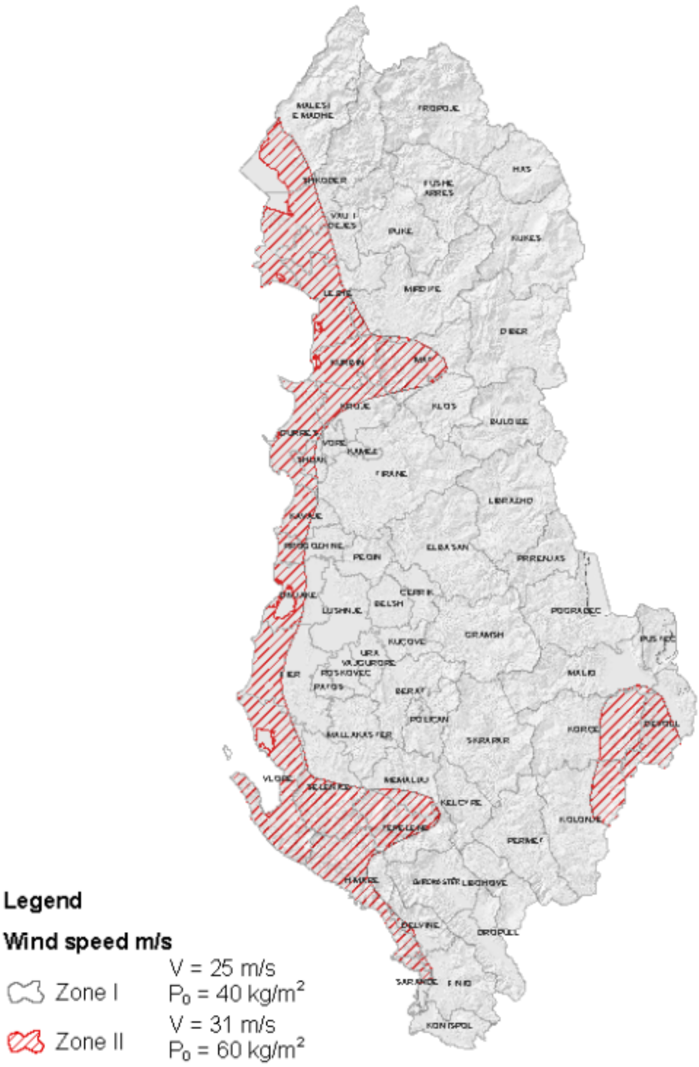


Figure 1. KTP 7-78 wind zones map

Where P_0 is the pressure calculated as $V^2/16$. The KTP-7-78 gives the reference pressure as $P=\rho{*}V^2/2$, and considers air density to be $\rho = 1/8$ ($kg{*}s^2/m^4$) [11]. To define wind pressure acting on structure the KTP-7-78 gives the following coefficients.

Firstly, is focused on terrain slope and ground altitude coefficient. Although there is no indication in code for slope limits, where terrain slope is significant, pressure should be increased by 1.2. In order to consider altitude effect on the wind pressure, KTP-7-78 [10, 11] gives a table of values for the correction coefficient (KB) for different ground altitude as can be seen in Table 1.

Table 1. Coefficients K_B used in KTP-7-78

GROUND ALTITUDE (M)	K_b
800	1
1200	1.8
1600	2.2
2000	3.0

For a better understanding of wind pressure, considering terrain slope and ground altitude coefficients, the wind map of 1x1 km grid is produced and presented in Figure 2.

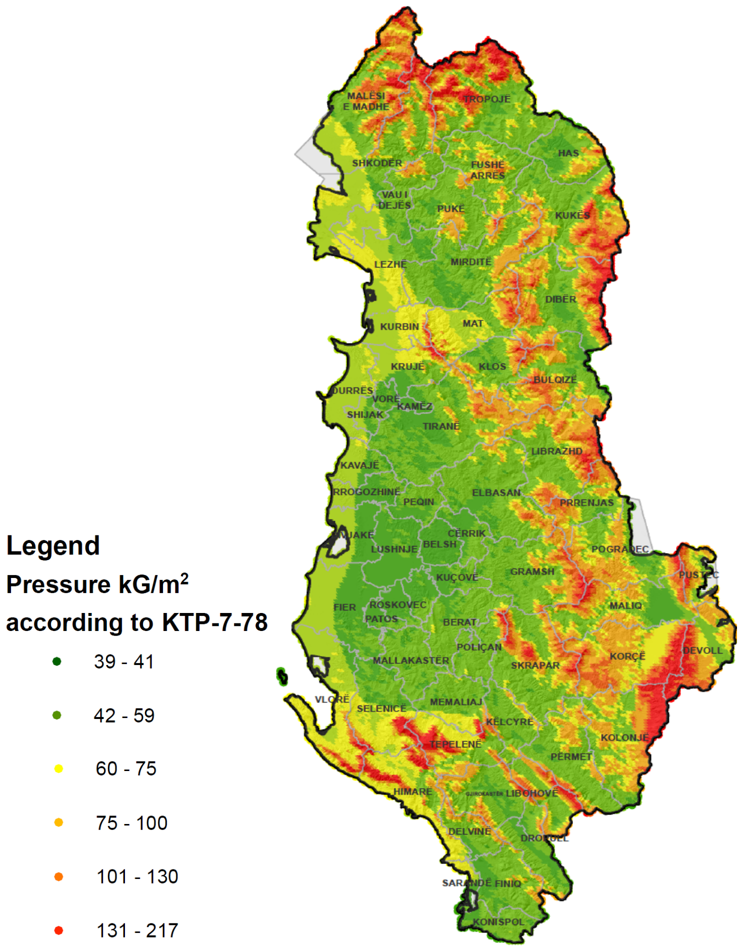


Figure 2. Modified KTP-7-78 wind speed map, including terrain slope and ground altitude coefficients

In order to apply pressure increase, a 10% slope threshold is considered in the map drafted for this purpose. The produced map, presented in Figure 2 shows that wind pressure to be considered in design differs substantially from the reference values given in Figure 1 due to terrain pattern.

Secondly is focused on the coefficients useage for structures height. For structures with height more than 10 m, coefficients (KA) are given in Table 2. For structures with height less than 10 m, KTP-7-78 do not indicate any wind pressure reduction coefficient.

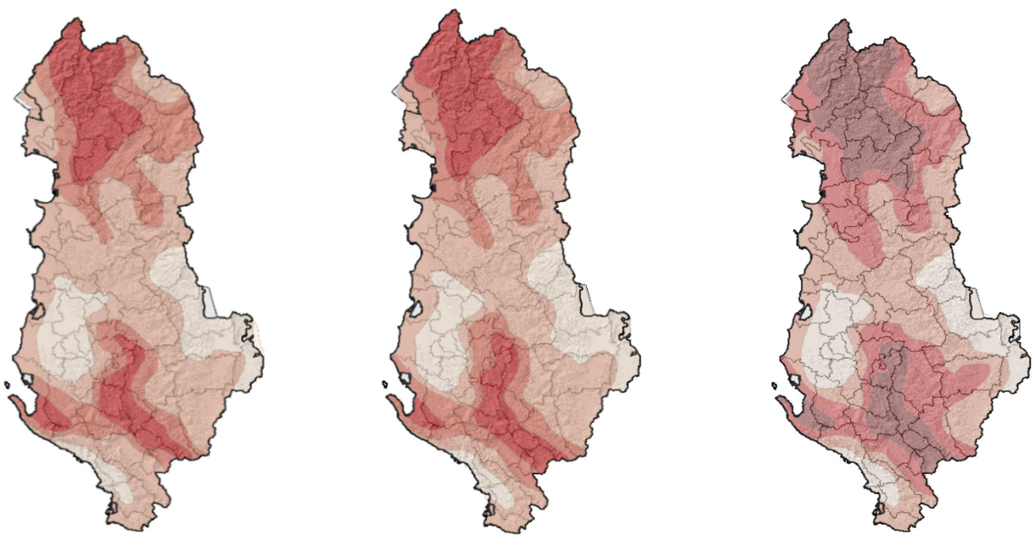
Table 2: Coefficients K_A used in KTP-7-78

STRUCTURES HEIGHT (M)	K_a
10	1.0
20	1.3
40	1.7
100	2.2

For both K_A and K_B interpolation is allowed in (KTP-7-78). KTP-7-78 does not give any information or references how the wind zones map is developed, nor for the PoE or duration of given wind speed. Meanwhile, considering the entire code package approved in 1978 (DCM 38 dated 03.05.1978) some cross references and interpretations can lead to the assumption that the reference design working life (50-100 years), given in [10], is taken into consideration for the proposed wind speed/pressure map.

Hydrometeorology technical code

An important information for wind speed can be found in Hydrometeorology technical code of 1981 [6]. This code gives maximum wind speed maps for 10%, 5%, 2% PoE, nevertheless, without necessary data or references to help understanding on how these maps are developed as well as no information about wind speed duration, see Figure 3. Darker colour zones represent highest wind speed.



(a) (b) (c)

Figure 3. KTHM 1-81 Maximum wind speed maps with PoE: (a) 10%, (b) 5%, (c) 2% – four wind zones.

Different colours in each map of Figure 3 represent four different zones of the country territory whereas the wind speed, related to different PoE, is given in the Table 3 for each of them.

Table 3. Wind speeds (m/s) for different zones and different PoE in accordance with [6]

Zone	10%	5%	2%
I	25	28	33
II	30	33	38
III	33	37	43
IV	35	40	46

Hydrometeorology technical code of 1990 [7] is a later publication of Hydrometeorology Institute in 1990 which redefines and updates wind zones. Still [7] does not give information about wind duration, but there are given coefficients that can be used to convert the given wind speed to the 10 min mean wind speed, as is referred on the Eurocode. Those coefficients vary from 1.4 to 1.5. Additionally, a factor in this range is used to convert wind speed used in different codes, e.g. to convert EN 1991-1-4 (ten minutes basic wind speed) to ASCE 7-16 (three second basic wind speed) a factor 1.432 is applied [1, 12-14]. Different colors of the map showed in the Figure 4 represent three different zones of the territory and the wind speed thresholds, with different probability of exceedance. These values are summarized in the Table 4.

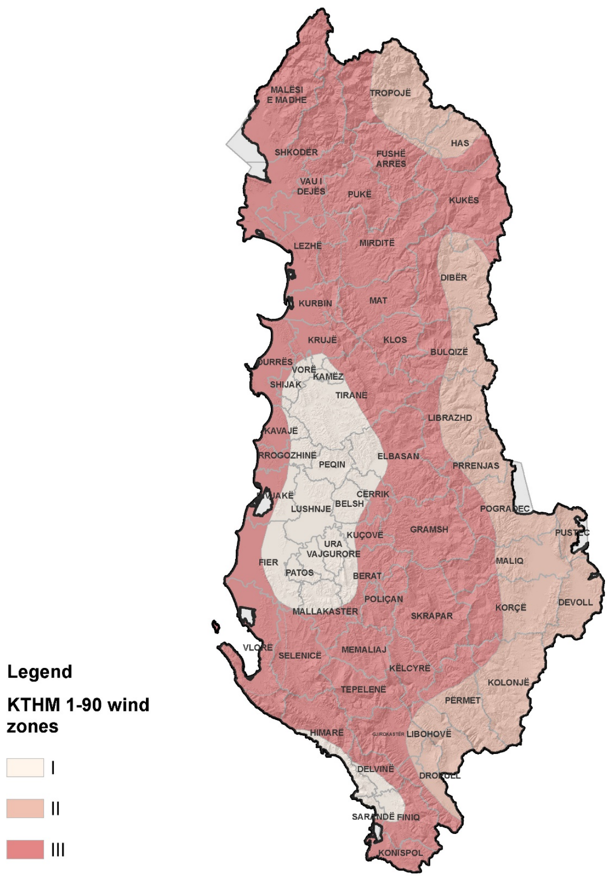


Figure 4. KTHM 1-90 Maximum wind speed map – three wind zones

Table 4: Wind speeds (m/s) for different zones and different PoE in accordance with [7]

Zone	20%	10%	5%	2%
I	18-20	20-23	23-26	17-30
II	10-23	24-27	28-30	30-33
III	24-37	28-30	31-35	35-40

Although there are changes in the findings and results presentation of both Codes: in the number of zones [6] divide the territory in four zones and [7] in three and in the way how the values are presented [6] gives determined values and [7] gives values in intervals, the maximum wind speeds values appear with no significant differences for low PoE.

DATA PROCESSING TO DEFINE FUNDAMENTAL BASIC WIND SPEED

Gumbel distribution fitting

Gumbel distribution, also known as Generalized Extreme Value Distribution, is the most recommended distribution for extreme values of a variable such as maximum wind speed. When available data are sufficient, PoE is calculated based on Gumbel distribution. Measured data for maximum wind speed in Tirana is given in "Davis Vantage Pro 2" station website [2]. Wind annual maximum speed in given in **Table 5** and are calculated based on Gumbel distribution parameters for the best fit distribution shown in equation (2).

$$\left.\begin{array}{ll} Location\ \ statistic & (M) = Mean - 0.45005 \cdot STD = 11.162 \\ Scale\ \ statistic & (B) = 0.7797 \cdot STD = 4.141 \end{array}\right\} \quad (2)$$

Table 5. Wind annual maximum speed [2]

Year	V_{max} (km/h)	V_{max} (m/s)
2010	38	10.556
2011	51.8	14.389
2012	98.2	27.278
2013	46.7	12.972
2014	38.6	10.722
2015	45.1	12.528
2016	38.6	10.722
2017	38.6	10.722
2018	43.5	12.083

Having Gumbel distribution parameters, peak wind flow can be calculated for any given PoE. The results from the best fit Gumbel distribution for this station are given in Table 6.

Table 6. Wind speed for given standard PoE

Prob.	Return period (years)	-ln(-ln(1-p))	Wind speed (m/s)
0.99	1.01	-1.52718	5
0.90	1.11	-0.83403	8
0.70	1.43	-0.18563	10
0.50	2	0.36651	13
0.20	5	1.49994	17
0.10	10	2.25037	20
0.05	20	2.97020	23
0.02	50	3.90194	27
0.01	100	4.60015	30
0.005	200	5.29581	33
0.002	500	6.21361	37

Wind speed corrections

Wind speed is measured including the effects of terrain roughness and orography. Correction of the wind speed to obtain a basic wind speed as defined in Eurocode (terrain roughness and orography) is used the inverse of expression given in the below sections of EN 1991-1-4 [1], expressed in equations (3) until (5).

$$V_b = \frac{V_m(z)}{C_r(z) \cdot C_0(z)} \tag{3}$$

Terrain coefficients, in accordance with Eurocode recommendations, for current station position are: Terrain category – IV; Height to ground level (Z) – 15m; Slope (ϕ) – 0.06; Orographic location factor (s) – 0.15. Using these data, roughness and orography factors can be calculate according to EN 1991-1-4:

$$\left.\begin{aligned} C_r(z) &= K_r \cdot \ln(z / z_0) = 0.843 \\ K_r &= 0.19\,(z_0 / z_{0,II})^{0.07} = 0.215 \\ C_0(z) &= 1 + \phi \cdot s = 1.009 \end{aligned}\right\} \tag{4}$$

and the obtained fundamental basic wind speed for Tirana is:

$$V_b = \frac{V_m(z)}{C_r(z) \cdot C_0(z)} = 31.76\ m/s \tag{5}$$

RELATIONSHIP BETWEEN EN 1991 1 4 AND NATIONAL TECHNICAL CODES WIND SPEED MAPS.

There exists a strong connection between KTP-7-78 and old Russian design code [15, 16]. KTPs are developed in a period of relevant influence of Russian literature, standards and design codes. Considering the detailed information given in [15, 16] (especially wind duration) and many similarities/identical sections, including measurement height, pressure and aerodynamic coefficients, can be assumed that the wind speed given in KTP-7-78 is the mean steady flow wind speed for a duration of 2 minutes measured 10 meters above the ground with 20% PoE. In order to convert/define the wind steady flow, from a given duration to another, Durst Curve [4] and the standard [14] may be used as can be seen in Figure 5.

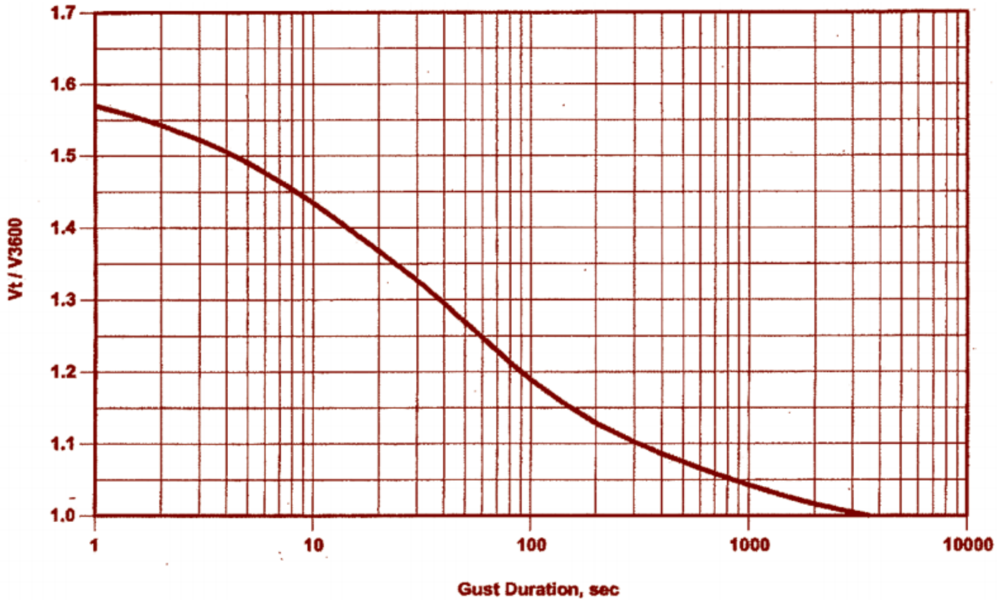


Figure 5. Durst curve for the conversion factor from one hour average steady flow to a lower duration steady flow [4].

The curve gives factors to one-hour steady flow, but it is also useful to determine relations between other durations. To determine V_{t1}/V_{t2} from the given V_t/V_{3600} the following formulae may be used:

$$\frac{V_{t1}}{V_{t2}} = \frac{V_{t1}/V_{3600}}{V_{t2}/V_{3600}} \quad (6)$$

Since the used curves of probability do not follow 1-hour average steady flow directly, applying Cprob to turn the values for 2% PoE and Durst Curve to convert 2 min to 10 min average speed may result in a false value. To convert 2 min, mean wind speed with 20% PoE to 10 min mean wind speed with 2% PoE, upgraded Russian code (SNiP 2.01.07-85, 1985) use a reduction coefficient equal to $1.15^{0.5}$ (in terms of wind pressure this coefficient is 1.15). Considering wind pressure ratio, Table 7 gives previous and modified wind pressure values, correlation between [16] and [15].

Table 7. Previous [16] and modified [15] wind pressure at the same zones

WIND ZONES	W_0, KPA [16]	W_0, KPA [15]
I_A	-	0.17
I	0.27	0.23
II	0.35	0.3
III	0.45	0.38
IV	0.55	0.48
V	0.7	0.60
VI	0.85	0.73
VII	1.00	0.85

The same ratio (the same reduction coefficient) would produce lower wind pressure values, moreover those values would not match with border countries references. Since the altitude effect is not explicitly included in (KTP-7-78) wind map and at the same time EN 1991-1-4 allows to consider altitude effect using corresponding coefficient, it was considered preferable to include altitude effect by using Calt=1.

Referring to the 2% PoE of maximum wind speed, the (KTHM 1-81) map represents altitude effects better than (KTHM 1-90) map. The last map has also some continuity issues, i.e. the wind zone I of (KTHM 1-90) map which is a zone with lowest wind speed values and is surrounded by wind zone III with highest wind speed values as shown in Figure 4. Moreover, (KTHM 1-81) results fit better with the measured and given data in other sources [2, 3, 5].

It is assumed that hydrometeorology technical codes give the "maximum wind velocity" for the minimum duration, i.e. 3 seconds. For structural design purposes that "maximum wind velocity" has to be used to define maximum peak and mean wind speed as defined in Eurocodes. So, in this study the existing maximum wind speed map with 2% PoE within 3 seconds wind duration is converted to 10 min mean wind speed, based on Durst Curve and the following coefficient is used for further analyses, see equation (7).

$$\frac{V_{600}}{V_3} = \frac{V_{600}/V_{3600}}{V_3/V_{3600}} = \frac{1.06}{1.52} = 0.697 \tag{7}$$

As mentioned above, hydrometeorology technical code (KTHM 1-90) recommends the use of a coefficient between 1.4 and 1.5 in order to convert the given data (max wind speed) to 10 min mean wind speed. The inverse of coefficient 0.697 that has been expressed at equation (7) is 1.43 and this value is applied on 2% PoE map of (KTHM 1-81). Furthermore, the wind zones with 2% PoE would become respectively shown at (8).

$$\left.\begin{array}{llll} Zone\ I & \rightarrow 33\ m/s & \rightarrow 23\ m/s \\ Zone\ II & \rightarrow 38\ m/s & \rightarrow 27\ m/s \\ Zone\ III & \rightarrow 43\ m/s & \rightarrow 30\ m/s \\ Zone\ IV & \rightarrow 46\ m/s & \rightarrow 32\ m/s \end{array}\right\} \tag{8}$$

Referring to Tirana which belong to the Zone III (43 m/s), basic wind speed value results almost the same with to the value calculated with Gumbel distribution is expression at equation (5). West part of Albania results with basic wind speed equal to 27 m/s which is relatively the same with Italy zone on the other side of Adriatic/Ionian Sea. Southern Part results with basic wind speed equal to 30-32 m/s and Greece on the border zone has a wind basic value of 30 m/s. Figure 6 depict existing wind speed map with 2% PoE. For low altitude areas of Albania (low terrain roughness) – mainly west territory, using the coefficient of $1.15^{0.5}$ of [15] and applying it to the (KTP-7-78) map, mean wind speed values will be seen in equation (9).

$$\left.\begin{array}{l} For\ \text{KTP}\ Zone\ I\ (KTP-7-78)\ 25/1.15^{0.5} = 23.31\ m/s \\ For\ \text{KTP}\ Zone\ II\ (KTP-7-78)\ 31/1.15^{0.5} = 28.91\ m/s \end{array}\right\} \tag{9}$$

Both fitting well with low terrain roughness within Zone I and II provided by expression equation (8). Thus, where altitude has no effect, or it is negligible the wind speed values result comparable in both maps which confirms the assumptions made previously in this section, to a satisfactory extension, see Figure 6.

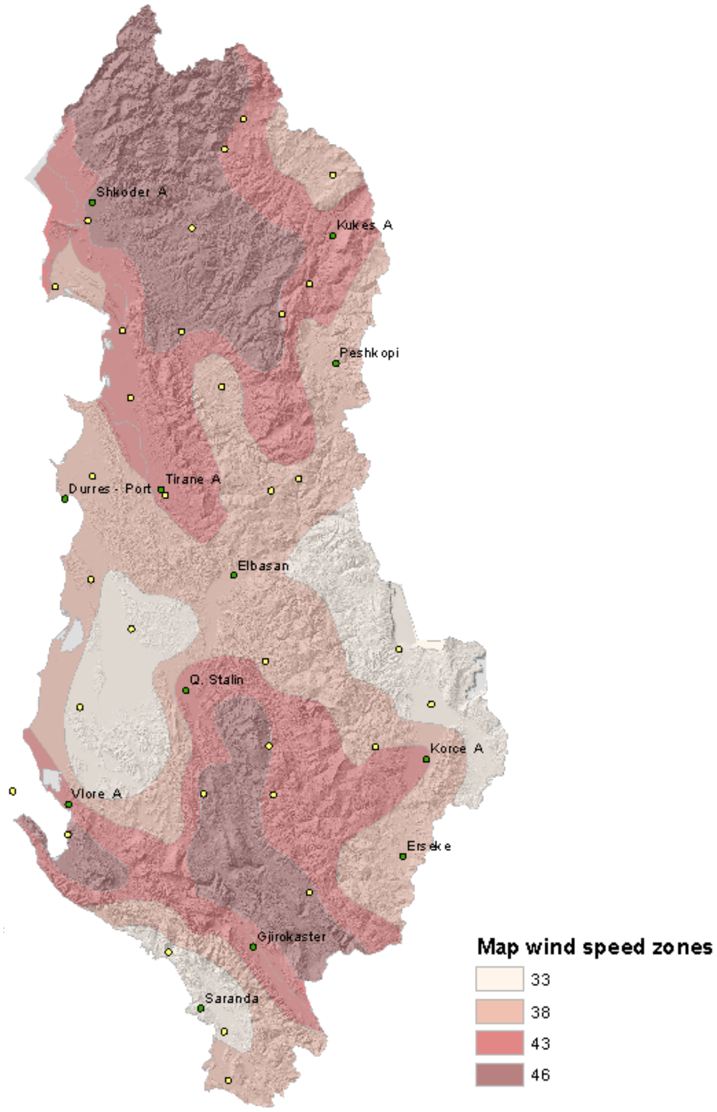


Figure 6. Existing wind speed map with 2% PoE, including meteorological stations [2, 6]

COMBINING THE APPROACHES

The map drafted using the reduction coefficient from (KTHM 1-81) map can be used as a base wind map, with the following changes: The zones with high altitude and Shkodra territory, defined in the existing 2% wind map with speed 46 m/s (within zone IV) will remain with the same shape. Vlora and Kuçova territory which are adjacent to zone IV should be unified with it since from periodic winds speeds, data given in literature and from respective stations, represent wind zones very comparable with Shkodra. Fundamental basic wind speed in sea and islands should be taken 32 m/s which is obtained from Durrës station (seaport station) using terrain reduction coefficient.

Applying changes in (KTHM 1-81) map show that these values are lower than those obtained from numerical approach given in Annex A for all station except Vlora. In fact, the results are shown in next section and are somehow conservative since respective calculations are not based totally on probabilistic methods and comprehensive data. Increasing the value of zone IV from 23 m/s to 25 m/s will cover other uncertainties affecting low boundary values and will make the zoning interval more uniform.

Following the Eurocodes requirements, for structural design purposes the wind speed map derived from (KTHM 1-81) with reduction factor 1.43 from expression of equation (7) fits better than wind speed map derived from (KTHM 1-90). For areas where altimetry is negligible, the results are satisfactory even using (KTP-7-78) map reduced by the coefficient 1.150.5 given in [15].

NUMERICAL APPROACH

Whenever wind data were available for different return periods, comparison with the recommended Eurocode data is made. The factor used in accordance with [1] to define wind speed for other PoE when the fundamental basic wind speed is given in formula 4.2 of EN 1991-1-4 is as follows:

$$C_{prob} = \left(\frac{1-K\cdot ln(-ln(1-P)}{1-K\cdot ln(-ln(0.98)}\right)^n \tag{10}$$

Where P is the probability of exceedance PoE, K is the shape parameter depending on the coefficient of variation of the extreme-value distribution; n – is the exponent. Maximum wind speed of different locations (stations) for different PoE (from 1% to 99% per year) is given in [5], but without additional information about duration of wind speed. This data-table is shown in Figure 7 and Table 8.

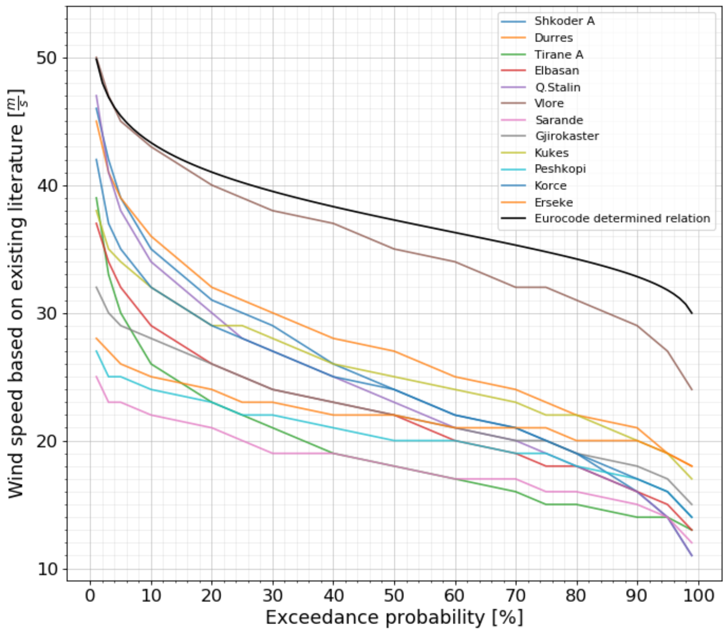


Figure 7. Wind speed PoE for some stations given by [5] compared with Eurocode correlation.

Table 8. Maximum wind speed (m/s) for different PoE [5]

Station	**1**	**3**	**5**	**10**	**20**	**25**	**30**	**40**	**50**	**60**	**70**	**75**	**80**	**90**	**95**	**99**
Shkodër a	46	42	39	35	31	30	29	26	24	22	21	20	19	16	14	11
Durrës	45	41	39	36	32	31	30	28	27	25	24	23	22	21	19	18
Tiranë A	39	33	30	26	23	22	21	19	18	17	16	15	15	14	14	13
Elbasan	37	34	32	29	26	25	24	23	22	20	19	18	18	16	15	13
Kuçovë	47	41	38	34	30	28	27	25	23	21	20	19	18	16	14	11
Vlorë	50	47	45	43	40	39	38	37	35	34	32	32	31	29	27	24
Sarandë	25	23	23	22	21	20	19	19	18	17	17	16	16	15	14	12
Gjirokastër	32	30	29	28	26	25	24	23	22	21	20	20	19	18	17	15
Kukës	38	35	34	32	29	29	28	26	25	24	23	22	22	20	19	17
Peshkopi	27	25	25	24	23	22	22	21	20	20	19	19	18	17	16	14
Korçë	42	37	35	32	29	28	27	25	24	22	21	20	19	17	16	14
Ersekë	28	27	26	25	24	23	23	22	22	21	1	21	20	20	19	18

For the comparison of the given values in EN 1991-1-4, which were estimated based on relation coefficient Cprob. The Eurocode curves shown in the chart correspond to recommended values of k and n respectively 0.2 and 0.5 and it is given only for comparison purpose. The values of wind speed in existing maps in Albania don't follow the same trend for all stations and for some of them since lacking enough data as well as due to uncertainty have been calculated in a conservative way.

Conservatively is represented graphically by the curve slopes or by difference of values on the left with high probability values which in all cases are based on low amount of data, and values on the right with low probability values, for which it may be assumed that enough data was provided to be correctly calculated. A comparison of obtained analysed data for Tirana, is given in the chart of Figure 8 which shows the differences between the curves

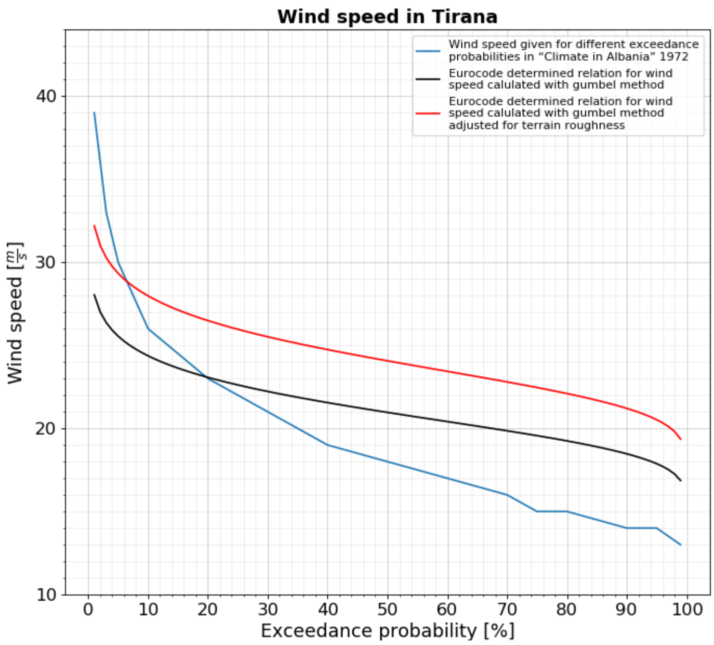
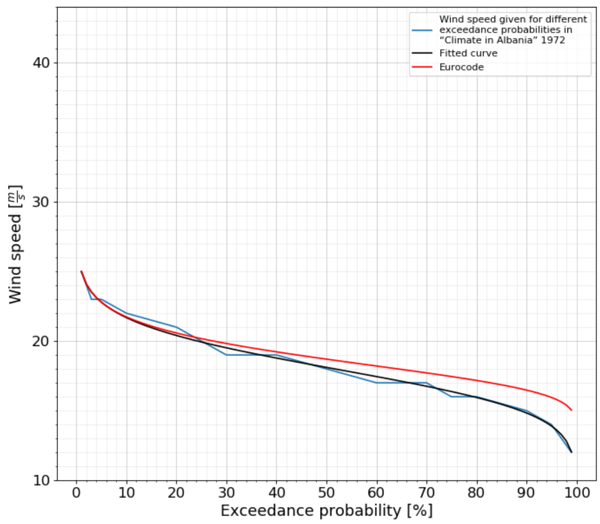


Figure 8. Wind speed for different PoE in Tirana station given in literature and map and compared with Eurocode correlation

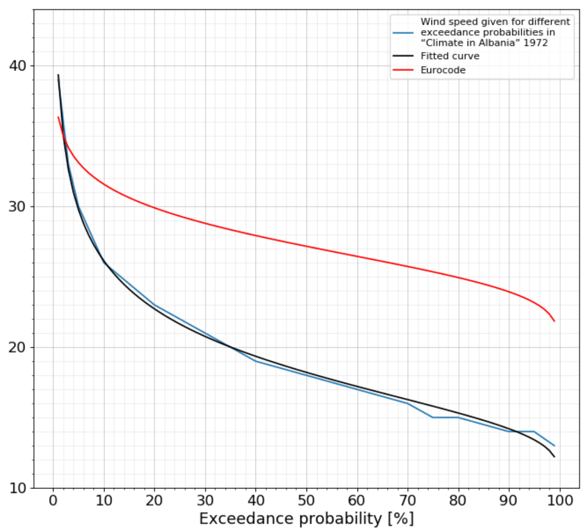
The slope difference for low wind speeds region is considerable. Moreover, the difference appears as well in case of wind speed with low probability, 2% PoE, which is even greater for other stations. Values within the range 10%-20% PoE are more likely near to real values, considering that the data for each station belongs to a period of 13 years. The wind speed map for 2% of PoE is used to calculate best-fit K, n, and $V_{2\%}$ curve parameters and C_{prob} is calculated using the formula in accordance with Eurocode, see equation (11):

$$V(P) = \left(\frac{1-K\cdot ln(-ln(1-P))}{1-K\cdot ln(-ln(0.98))}\right)^{n} \cdot V_{2\%} \quad (11)$$

Values given for Gjirokastër, Peshkopi, Erseka and Saranda produce a satisfactory match with the Eurocode Curve, whilst not giving the same fitting curve for Tirana, see Figure 9.



(a)



(b)

Figure 9. Calculated best fit curve parameters and comparison with eurocode recommended parameters: (a) Saranda (satisfactory correlation), (b) Tirana (not satisfactory correlation)

To correct the wind speed values, calculated parameters for $P_1 < 2\%$ PoE will be used, continuing further with calculation of the basic wind speed using Eurocode recommended parameters. This correction considers the differences in values of given wind speed for different PoE and recommended ones.

In case of Tirana, where basic wind speed is also calculated from measured data at above section, the correct P_1 value to use is 10%. Lower probabilities give a more conservative basic wind speed values and higher probabilities give lower basic wind speed values. Applying the described method for Tirana with $P_1 = 5\%$ would result in a similar basic wind speed value as the one calculated with Gumbel distribution (adjusted for terrain roughness), but it will also produce slightly more conservative value.

This method provides decreased values for stations which have a rapid increase of given wind speeds for low probabilities and tend to give approximately the same values for those stations following the curve given in Eurocode, see Table 9.

Table 9. Best fit curve parameters

STATION	$V_{2\%}$	K	N
SHKODËR A	43.37	0.429	0.687
DURRËS	42.63	0.244	0.801
TIRANË A	34.81	0.111	2
ELBASAN	35.03	0.297	0.733
KUÇOVË	43.19	0.335	0.869
VLORË	48.08	0.366	0.409
SARANDË	24.09	0.425	0.342
GJIROKASTËR	30.99	0.355	0.447
KUKËS	36.38	0.320	0.524
PESHKOPI	26.05	0.459	0.280
KORÇË	39.01	0.309	0.737
ERSEKË	27.27	0.190	0.454

The calculated and different fitting curves for Tirana are shown in Figure 10.

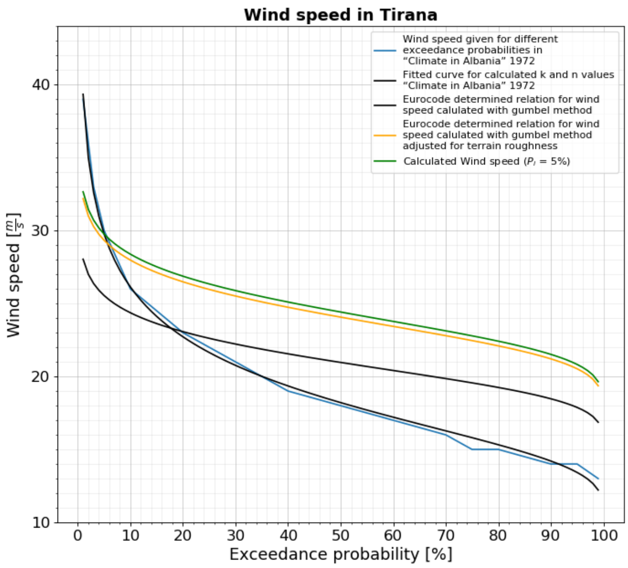


Figure 10. Wind speed in Tirana for P1 = 5% and comparison with Gumbel and data from [5]

Calculated basic wind speeds for all the stations given above are shown in the Table . The PoE equations derived from wind speeds data given in national literature and code maps differs considerably from that given in (EN 1991-1-4), therefore may be assumed that those data and maps do not represent 10 min average speeds, see Table 10.

Table 10: Wind speeds calculated from the above described method using P1 = 5%.

Year	V_{MAX} (km/h)	V_{MAX} (m/s)
Shkodër A	46	38.9
Durrës	38	39.3
Tiranë A	43	29.3
Elbasan	38	32.1
Kuçovë	43	37.7
Vlorë	43	47.4
Sarandë	33	24.0
Gjirokastër	43	30.3
Kukës	43	35.0
Peshkopi	38	26.4
Korçë	43	35.6
Ersekë	38	27.6

From the above results we have proposed fundamental basic wind speed map for Albania (C_{alt} = 1) as can be seen in Figure 11.

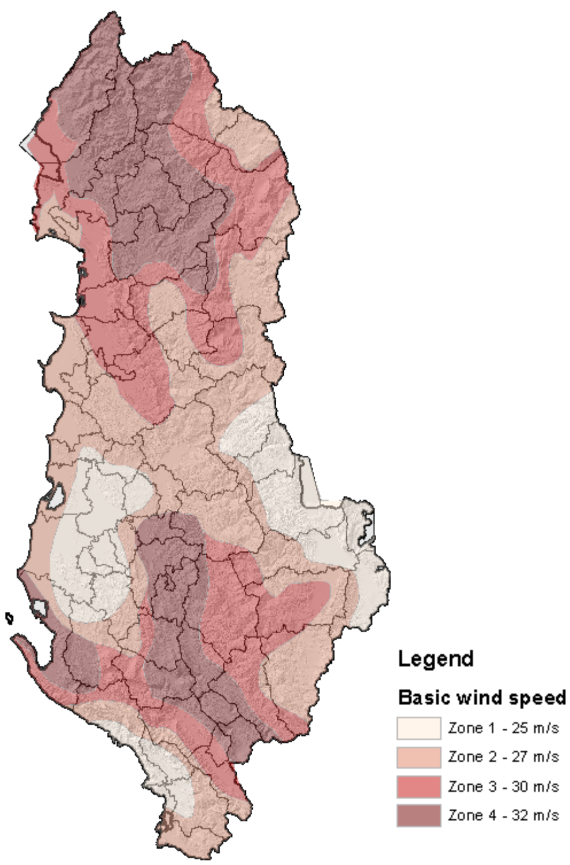


Figure 11. Proposed fundamental basic wind speed map for Albania (C_{alt} = 1)

CONCLUSION

The preparation of a fundamental basic wind speed map, based on a whole set of statistical measured data, is essential. Meanwhile, the conclusions and the proposed map of this study may be used for structural design purposes in accordance with Eurocodes requirements, during transition period. Based on all available data, KTP Wind zones map at [9] is drafted considering 2-minute average wind speed with 20% PoE. Other wind speed maps at [6, 7] and maximum wind speed tabular data corresponds to very low duration wind speeds, most probably 3 sec duration. If more reliable data will be available in the future, a further assessment need to be carried out. It is recommended to use an additional coefficient for construction works situated in boundaries between different terrain categories and those near to the seashore which is subject of wind speeds unreduced for terrain roughness.

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CONFLICT OF INTERESTS

The authors confirm that there is no conflict of interests associated with this publication.

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