

Wind Load Characteristics in Libya

Mohammed B. Abohedma, and Milad M. Alshebani

Abstract—Recent trends in building constructions in Libya are more toward tall (high-rise) building projects. As a consequence, a better estimation of the lateral loading in the design process is becoming the focal of a safe and cost effective building industry. By-in-large, Libya is not considered a potential earthquake prone zone, making wind is the dominant design lateral loads. Current design practice in the country estimates wind speeds on a mere random bases by considering certain factor of safety to the chosen wind speed. Therefore, a need for a more accurate estimation of wind speeds in Libya was the motivation behind this study. Records of wind speed data were collected from 22 metrological stations in Libya, and were statistically analysed. The analysis of more than four decades of wind speed records suggests that the country can be divided into four zones of distinct wind speeds. A computer “survey” program was manipulated to draw design wind speeds contour map for the state of Libya.

The paper presents the statistical analysis of Libya’s recorded wind speed data and proposes design wind speed values for a 50-year return period that covers the entire country.

Keywords—Ccontour map, return period, wind speed, and zone.

I. INTRODUCTION

THE growing trend towards construction of high-rise structures in recent Libya’s development plans, requires a more accurate estimation of wind loads. The future skyline of Tripoli city will include towers and tall buildings that well exceed 50 storeys high. By-and-large Libya is not considered an earthquake prone zone, and therefore, wind loads are the most dominant lateral loads in the design of tall buildings. Past practice by the country’s design engineers estimates wind speed rather randomly in lieu of reliable documented wind data. Over the past decades, a number of over-head transmission steel towers have collapsed because, the wind load incorporated in the design of some zones was underestimated. More recently, an RC mosque’s minaret of 60m high under construction had failed due to wind load exceeding the design value.

Because of Libya’s large area (more than 1,700,000 square kilometers), winds fluctuate largely in speed and directions from region to region within the country boundary zones. It is

the focus of this study to quantify such fluctuation in order to arrive to design basic wind speeds that can be used for structural design when wind loads govern. Furthermore, the finding of this research could explore other wind application such as generation of electricity.

II. EVALUATION AND REPRESENTATION OF WIND VELOCITY

Wind loads on structures need to be estimated with good accuracy, which requires better understanding of wind speeds. Because wind speed is a probabilistic event, researchers have extensively studied the probability distribution function that better fit the extreme value of wind speed. Type I extreme value distribution is widely used to evaluate the design wind speed values. Wind velocity in different regions can well be represented by using contour levels. Many countries have produced its own wind velocity or wind related maps. ANSI produced basic wind speed map for USA along with special wind region [1]. The isotaches of the contour map produced by ANSI represent the *fastest-mile* velocities at 10m above the ground [1].

A study on the hurricane important factor of the design wind speed in the Caribbean region allows for it to vary with location rather than using a fixed value [2]. The effective wind load factor $(V_T/V_{50})^2$ was then used to plot the contour map over the Caribbean for specific effective wind load factor duration ($T = 700 \text{ years}$) [2].

A revised wind speed map for India was recently produced. The revised map is based on Type I distribution analysis for long-term data on hourly wind speed including daily gust wind speed [3]. The revision in general suggested an increase in the design wind speed value by as much as 20% which in turn upgraded some zones by 2 levels [3].

III. WINDS IN LIBYA

Libya is affected by atmospheric depressions during the winter time and northeastern trade winds in the summer. Libya is also exposed to “*Ghibli*” winds, a dry and hot wind that blows from the south several times a year most notably from late spring throughout summer season [4].

There are 22 synoptic stations (land stations) scattered within the boundary of Libya, and the oldest station is about 50 year old. Time of observation of these synoptic stations adheres to the international guidance of main standard times [5], [6]. These synoptic stations use cup anemometer to measure the wind velocity.

In earlier applications some wind codes are based on (*fastest-mile wind speed*). However most codes nowadays use

Mohammed B. Abohedmh is a postgraduate of Civil Engineering Department, Alfateh University, Tripoli, Libya (e-mail: m.abohedmh@yahoo.com).

Prof. Milad M. Alshebani is with the Department of Civil Engineering Alfateh University, Tripoli, Libya (e-mail: milad53@hotmail.com milad@alemaad.com).

the average t-time gust wind speed. In Libya measurement is based on *10-sec gusts wind speed*.

IV. ANALYSIS METHODOLOGY

The analysis methodology of wind speeds in Libya follows the sequences as in the following chart in Fig. 1.

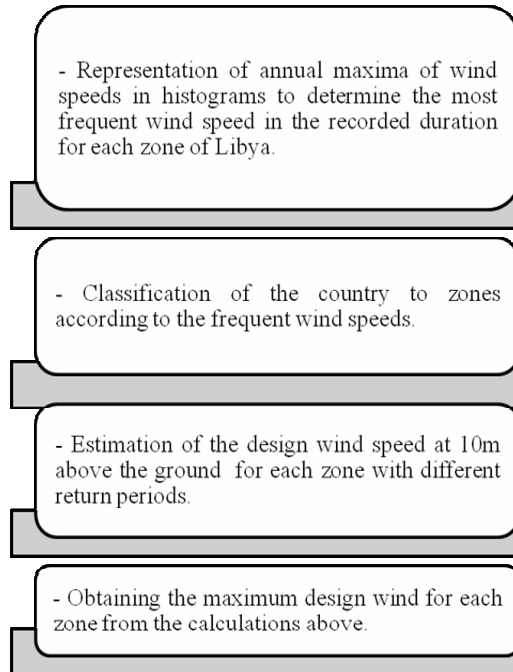


Fig. 1 Flowchart of wind speed data analysis

In certain stations, however, there are some missing readings due to unavoidable problems. An averaged wind speed for corresponding months is placed for the missing records.

A. Wind Data Histograms

A statistical analysis computer program known as (*SPSS*) was used to draw histograms for the recorded wind data collected from each station. Figure. 2 shows a typical wind histogram for the city of Agedabia.

These histograms are then used to define the most frequent speed over a certain period. The most frequent wind speeds for all 22 stations are given in (see Table I).

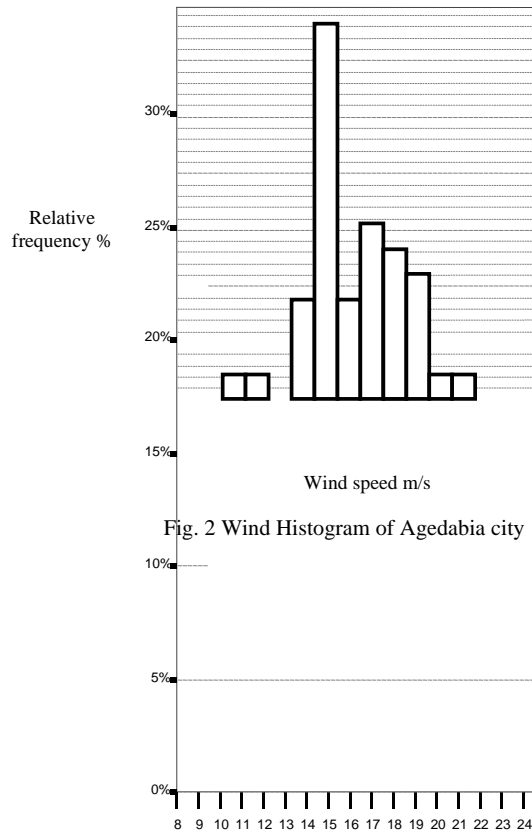


Fig. 2 Wind Histogram of Agedabia city

TABLE I
THE MOST FREQUENT WIND SPEEDS FOR 22 CITIES IN LIBYA

| Station name | The most frequent wind speed (m/s) | Station name | The most frequent wind speed (m/s) |
|--------------|------------------------------------|--------------|------------------------------------|
| GHARIAT | 20 | OBARI | 15 |
| TAZERBO | 15 | DERNA | 23 |
| SEBHA | 20 | SHAHAT | 23 |
| GHAT | 18 | MISURATA | 15 |
| JAGHBOUB | 18 | HON | 20 |
| AGEDABIA | 15 | ALKOMES | 18 |
| ELKUFRA | 18 | BENINA | 18 |
| JALO | 15 | ZUARA | 18 |
| SIRT | 18 | TUBRK | 20 |
| GHADAMES | 20 | TRIPOLI | 15 |
| | | AIRPORT | |
| NALUT | 20 | YEFran | 18 |

B. Wind Speed Zones

By examining wind speeds and its frequent durations, it has been envisioned that Libya can be classified into *four wind speed zones* in ascending order of its annual maxima wind speed. It is assumed, therefore, that the most frequent wind speed at any location in the country should belong to one of the four established zones.

Wind speeds that do not exactly correspond to the wind zone, should be assigned to the nearest upper level zone.

C. Estimation of Design Wind Speed

Gumble's method of fitting recorded annual maxima to the Type I extreme value distribution was used in this analysis [7], [8]. The cumulative function, $F(U)$ of the Type I distribution is represented in (1).

$$F(U) = \exp \{ - \exp [- (U - u) a] \} \quad (1)$$

Where

U = the wind gust speed
 u = the mode of the distribution
 a = the scale factor

The parameters u & a were calculated approximately by using (2), (3) respectively

$$a \approx (\sqrt{6/\pi}) \sigma \quad (2)$$

$$u = \mu - 0.5772 a \quad (3)$$

Where

R = the return period in years

U_R = the wind gust speed corresponding to return period, R

Therefore, by establishing the annual maxima for each station, equation (3) can easily be evaluated for certain return period. The previously established zone numbers by this study has now to be numbered in an ascending wind speed order. Table II shows the design wind speed for each zone with a 50 – year return period.

TABLE II
NEW DESIGNATION OF WIND SPEED ZONES

| Previous numbering of zones | New designation of zones | The design wind speed with a return period 50 year (Km/h) |
|-----------------------------|--------------------------|-----------------------------------------------------------|
| 1 | 1 | 105 |
| 3 | 2 | 110 |
| 4 | 3 | 115 |
| 2 | 4 | 121 |

V. WIND VELOCITY CONTOUR MAP

A computer program called (*Surfer*) was utilized to draw the wind velocity contour map for the entire country. The input data for the computer program consists of 3-D coordinate points (x, y, and z). The coordinates x and y represent the longitude and latitude position of each station respectively, while the altitude (z coordinate) is replaced by design wind speed at the station.

The output of the program is illustrated in Fig 3, which shows the four zones design wind speed mapped over the entire area of Libya. To distinguish each zone's area of dominations, the zones are drawn with different colors.

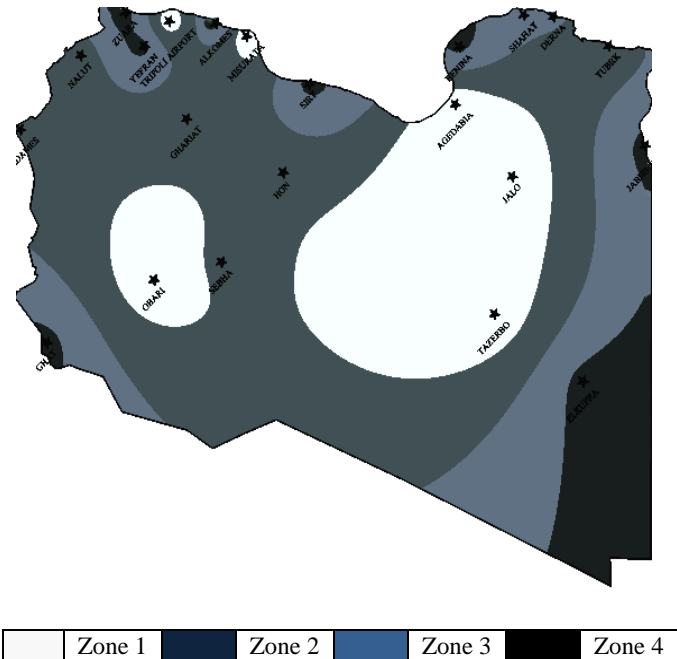


Fig. 3 The design wind speed contour map of Libya with a 50- year return period at 10 m above the ground

VI. DISCUSSION OF THE RESULTS

The study is based on the inventory of more than 40 years of wind speed data collected from 22 stations. The data did not show unusual wind speeds as the stations recording system do not have the capability of capturing such events. Gaps of no recording were dealt with by averaging wind speeds from corresponding months.

Histograms of wind speeds are drawn for each station to display the annual maxima. Type I extreme value distribution was used to evaluate the design wind speed. The probability distribution function is chosen for simplicity as it only requires the determination of the distribution parameters (a , u). These parameters can easily be calculated once the mean (μ) and the standard deviation (σ) are established.

The design wind speeds were calculated for a 50 – year return period, though speeds for 75 and 100 – year return period were also established for comparison.

It was envisioned that Libya can be divided into four zones of design wind speeds with a 50 – year return period. The zones are designated by numbers 1 to 4 according to the ascending order of zone's basic wind speeds. A computer software contour program called (*Surfer*) was manipulated to map the four zones over the territory of Libya. It was clear from the zone map that zone no. 2 covers about 50% of the country's area with design wind speed = 110 Km/hr . Zone no. 4 is the highest design wind speed zone, yet it represents only about 10% of the country's area.

VII. CONCLUSIONS AND RECOMMENDATIONS

1. An inventory of wind speed records was established from 22 meteorological stations around the country. The inventory represents more than 4 decades of recording of wind speeds at 10m above the ground.
2. Gaps of no records were found in some stations for certain period and it was dealt with by averaging the records of corresponding months. There was no recovery of unusual wind speed events.
3. It was envisioned that the country territory can be classified into four wind speeds zones with designation numbers from 1 to 4.
4. Type I extreme value probability distribution was chosen to evaluate the design wind speed for each station with a 50 – year return period.
5. A computer contour program was utilized to plot the wind speed contours which then mapped over the entire area of the country. The four zones have each been given a different color for easy distinction.
6. Future update to this study requires expansion of the current stations network, employ more fully automatic synoptic stations and provide database for unusual wind speeds.
7. Since the stations record cannot be completely reliable and because of current climate change, it is recommended to increase the design wind speed reported in this study by a factor of safety = 1.25.

REFERENCES

- [1] Bunglale S.Turanath, " Structural Analysis and Design of Tall Buildings ", McGRAW, 1988.
- [2] P. J. Vickery and D. Wadhera, " Wind Speed Maps for the Caribbean for Application with the Wind Load Provisions ASCE-7 " , Applied Research Associates, 7-2875. 2003.
- [3] N. Lakshmanan, S. Gomathinayagam, P. Harikrishna, A. Abraham & S. Chitra Ganapathi, " Basic Wind Speed Map of India with Long-term Hourly Wind Data ", Current Science, Vol.96, No.7, 10 April 2009.
- [4] Dr.Moahammed.Almabrouk.Almahdi, "Libyan Habitat Geography ", Ghariuness University publication, Libya, 1988 (In Arabic).
- [5] Dr.Salah.Bashier.Mossa, " Natural Climate ", Modern Academic Office, Alexandria, 2005 (In Arabic).
- [6] World Meteorological Organization, " Compendium of Lecture Notes for Training Class IV Meteorological Personnel ", WMO – No. 266.
- [7] John D. Holmes, " Wind Loading of Structures ", Second Edition, Taylor & Francis, 2007.
- [8] Bilal M. Ayyub & Richard H. McCuen, " Probability, Statistics and Reliability for Engineers and Scientists ", Second Edition, Chapman & Hall/CRC, 2003.
- [9] Dorvlo, A.S.S. " Estimating Wind Speed Distribution ", Energy Conversion and Management 43, 231-2318, 2006.
- [10] Leiblein, J., " A New Method of Analysing Extreme Value Data ", NACA TN 3053, 1954.
- [11] Gracia, A., Torres, J.L., Prieto, E., & DeFrancisco, A., " Fitting Wind Speed Distribution ", Solar Energy 2, 139-144, 1998.
- [12] Murthy, D.N.P., Xie, M., and Jiang, R. , " Weibull Models ", John Wiley & Sons, New Jersey, 2004.