MATEC Web of Conferences **117**, 00023 (2017) DOI: 10.1051/matecconf/201711700023
XXVI R-S-P Seminar 2017, Theoretical Foundation of Civil Engineering

Data bases of aerological wind observations for industrial and civil construction

Fedor Bryukhan[1,*]

[1] Moscow state university of civil engineering, Yaroslavskoye shosse, 26, Moscow, Russia, 129337

Abstract. Due to extensive construction of high-rise buildings and structures, wind load calculations are becoming more and more important. These calculations require availability of credible wind data at the altitude of the atmospheric boundary layer and associated databases. This work is devoted to development of a framework for such databases, aimed at solution of various wind engineering tasks. Main principles for wind aerological observation database development for industrial and civil construction were established. Examples of wind characteristics and atmospheric dispersion characteristics are provided on the basis of radiosonde and SODAR/RASS observations. Prospects for development of similar databases for atmosphere pollution monitoring, wind power engineering, aviation are reported.

1 Introduction

Many buildings and structures 300-500 m high and more have been built or designed. These include Burj Khalifa building (Dubai, 828 m), Tokyo Skytree television tower (Tokyo, 634 m), Shanghai Tower (Shanghai, 632 m) and others. Besides this, many heat power stations use smoke stacks 200-400 m high. Taking into account that the wind speed progressively increases with the altitude, the wind exerts considerable loads on these buildings and structures [1, 2].

Design of high-rise buildings and structures requires calculation of static and dynamic load loads for development of engineering solutions for safe operation assurance [3]. Besides credible calculation models of wind loads, reliable wind observation data and related databases adapted to calculation models are required.

Most wind load calculations used ground meteorological observation data, extrapolated to the altitudes for which loads are determined [4]. However, due to diversity of atmosphere vertical stability types and the effect of wind vector rotation in the atmospheric boundary layer (ABL), actual wind characteristics and, therefore, wind loads differ from model loads very much. Due to the above circumstances, the most preferable wind data are observations at ABL altitudes. Such observations are carried out by using either radiosonde or acoustic sounding systems.

As applied to specific wind engineering tasks, one of the above observation methods is used, and sometimes – a combination of the two.

---

[*] Corresponding author: pniiis-gip@mail.ru

2 Measurement systems and databases of wind observations

Radiosonde systems for meteorological parameters measuring a hydrogen or helium-filled latex balloon with an attached temperature, pressure and humidity sensor is launched into the atmosphere. Measurement results and current coordinates of the balloon are received by a radio locator. Based on the balloon flight coordinates the wind speed and direction are determined. First of all, radiosonde observations are aimed at meteorological data acquisition for weather forecasting. However, ABL wind measurements can be used in wind engineering, for studying pollutant propagation in the atmosphere (atmospheric dispersion) and for other tasks.

Radiosonde data are stored in special archives for a 40-50 year period of observations at more than 100 observation points across the ex-USSR territory. Such data support calculations of various climatic atmosphere characteristics for a wide range of applications [1, 5]. Unfortunately, since 2015 the network of Russian aerological stations started to perform only 1-2 soundings per day instead of 2-4. In such situation, radiosonde data cannot fully support reliable load calculations since at low altitudes (up to 300-500 m) ABL meteorological parameters greatly vary within 24 hours.

The most suitable method for wind engineering is the ABL acoustic sounding using wind radio acoustic sodars. The operating principle of sodars is similar with that of radars. The difference is that sodars use acoustic impulses instead of electromagnetic impulses sent by radars. Based on such acoustic signal, reflected from turbulent atmospheric irregularities, the sodar integrated software determines atmospheric turbulence characteristics, including the wind vector. Unlike radiosonde systems, sodars enable virtually continuous acquisition of wind speed and direction data at the time resolution of about 10 minutes [6, 7]. The upper ABL sounding limit for sodars is about 1 km and is sufficient for wind load calculations. Another important fact is that sodars enable acquisition of wind data averaged to 10-minute intervals, normally used for wind load calculations.

For atmospheric dispersion studies the SODAR/RASS system (sodar coupled with the radio acoustic sounding system – RASS) is used [7, 8]. The operating principle of the temperature profile meter is that it sends electromagnetic waves, which are reflected from atmosphere irregularities, produced by acoustic waves from sodars. Electromagnetic waves reflected from such structural irregularities produce the diffraction effect and are received by the RASS antenna. Based on the received signal the sound speeds and consequently the air temperatures at different altitudes are determined [7].

The main disadvantage of sodars is that they have been widely used only for a relatively short period and no long-term data have been collected.

First automated archives of ABL radiosonde observation data were developed in the 1970's and their network covered 146 aerological stations in the USSR [1]. As the data were accumulated and their processing methods improved, the database structure and content changed considerably [5]. Since January of 1964 till present the All-Russian Research Institute for Hydrometeorological Information – World Data Centre has accumulated an immense data array for the Russian aerological network [9]. This array includes standard atmosphere sounding data, as well as information on specific points of vertical temperature and wind profiles, where the linearity of their vertical profile variations is disrupted. Additionally, the array includes ABL altitude data. Respective databases are presented by long-term months, but can be easily transformed in the chronological sequence. Data control, their vertical interpolation and statistical processing are performed by specialized software for calculation of various characteristics.

As the remote ABL sounding is carried out using the SODAR/RASS complex, current month readings are recorded and databases are formed. It is followed by data control and statistical processing, usually by current seasons, years and for a long-term period. As the remote ABL sounding is carried out using the SODAR/RASS complex, current month readings are recorded and databases are formed. It is followed by data control and statistical processing, usually by current seasons, years and for a long-term period.

3 Examples of database application

Below are examples of calculations of different wind and atmospheric dispersion characteristics using radiosonde and SODAR/RASS observation databases.

3.1 Radiosonde observation data

Tables 1 and 2 show the basic average annual wind characteristics according to the Nizhny Novgorod aerological station after long-term averaging. Table 1 shows rapid increase of the wind speed with the altitude. The mean value modulus of the wind vector is considerably lower than the average speed. This circumstance indicates frequent changes in the wind direction. The prevailing wind direction is western.

Table 1. Average annual wind characteristics at heights. Averaging period 1964-2012. Nizhny Novgorod.

Height, m	Average speed, m/s	Average value of the wind vector	
		Module, m/s	Direction, degrees
0	2.6	0.5	240
100	4.0	1.2	244
200	5.0	1.7	248
300	5.8	2.1	251
500	7.2	2.9	256
1000	8.9	4.0	261

Table 2. Average annual combined repeatability of wind speed and direction in 8 compass points at 300 m. Averaging period 1964-2012. Nizhny Novgorod.

Speed, m/s	Compass points								Calm	Sum
	N	NE	E	SE	S	SW	W	NW		
Calm	–	–	–	–	–	–	–	–	0.97	0.97
1	0.72	0.56	0.60	0.58	0.69	0.75	0.90	0.88	–	5.68
2	1.21	1.01	0.93	0.91	1.12	1.30	1.45	1.77	–	9.69
3	1.60	1.20	1.04	1.07	1.23	1.71	2.38	2.27	–	12.51
4	1.94	1.16	0.93	0.89	1.31	1.81	2.73	2.44	–	13.21
5	1.84	0.96	0.81	0.88	1.16	1.85	2.57	2.54	–	12.62
6-10	4.82	1.93	1.63	2.25	3.03	5.73	7.86	7.06	–	34.31
11-15	0.85	0.29	0.35	0.54	1.01	1.81	2.49	1.61	–	8.93

Table 2 – continuation.

Speed, m/s	**Compass points**								**Calm**	**Sum**
	N	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**		
21-25	0.02	0.00	0.00	0.00	0.04	0.11	0.18	0.04	–	0.40
26-30	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	–	0.03
> 30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–	0.00
Sum	13.07	7.14	6.35	7.18	9.85	15.48	21.12	18.83	0.97	100.00

Table 2 shows aggregate average annual combined repeatability of wind speed and direction in 8 compass points (complex wind rose) at 300 m for the same averaging period. Data from Table 2 confirm the fact that westerly winds prevail. Zero wind repeatability is low, less than 1%.

In the provided examples and below the wind direction is meteorological and means the azimuth of the direction from where the wind blows.

3.2 SODAR/RASS measurement results

As an example of practical application of SODAR/RASS measurement data, Figure 1 shows the horizontal distribution of the average annual coefficient of meteorological radionuclide dilution (ratio of radionuclide concentration to emission rate) near the Belorussian nuclear power plant. The averaging period is January-December of 2015. Calculations are made using the Gaussian dispersion model [10].

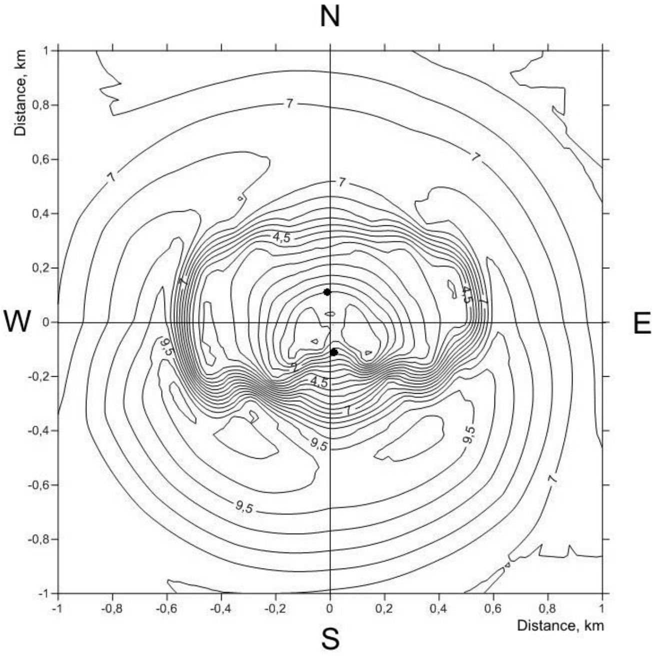

Fig. 1. Horizontal distribution of the average annual coefficient of meteorological dilution ($10^6 \times s/m^3$) at the ground level in normal operating conditions of the nuclear power plant. Emission source height is 100 m. Dots near the center indicate vent pipe locations.

4 Other fields of application for aerological databases

Fields of practical application of aerological observations, especially SODAR/RASS measurement results, are not limited to the above. Such measurements are widely used in air pollution monitoring in big cities, in wind engineering, in aviation.

Monitoring of meteorological parameters, determining pollutant dispersion conditions, becomes more and more important due to dependence of the big-city population health on the atmospheric air quality. Statistical analysis of atmospheric dispersion characteristics, measured by SODAR/RASS, enables development of air protection measures [11].

Radiosonde systems and sodars used in wind engineering support wind observations for assessment of wind-power resources. Such assessment are necessary for selection of locations for wind power stations and for generated power forecasting [12, 13].

Atmospheric vortexes, vertical wind shears, speed of winds transverse to runways are important factors that affect the safety of plane takeoff and landing [14]. Relevant operational information is provided by sodars.

The mentioned areas of application for sodar or SODAR/RASS measurements required development of relevant specific databases.

5 Conclusions

- Basic principles for development of aerological wind observation databases are established for solution of wind engineering tasks in industrial and civil construction.
- Examples of calculations of various wind characteristics, as well as atmospheric dispersion characteristics using radiosonde and SODAR/RASS observation databases are provided.
- Reference is made to potential development of similar databases in other areas: in air pollution monitoring, wind power engineering, aviation.

Acknowledgments

The author thanks Dr O.A. Alduchov, the Leading Researcher of the All-Russian Research Institute for Hydrometeorological Information – World Data Centre for useful discussions.

References

1. F.F. Bryukhan, *Methods of climatologic processing and analysis of aerologic information* (Gidrometeoizdat Publishing House, Moscow, 1983)
2. N. Perlin, S.P. De Szoeke, D.B. Chelton et al., Mon. Weather Rev., **142**, 4284-4307 (2014)
3. E. Simiu, R. Scanlan, *Wind effects on structures: an introduction to wind engineering* (J. Wiley & Sons, New York, 2000)
4. A. Peña Diaz, S.-E. Gryning, C.B. Hasager, Bound.-Lay. Meteorol., **129**, 479-495 (2008)
5. O.A. Alduchov, I.V. Chernykh, *Methods of analysis and interpretation of the atmosphere radio-sound observations data: quality control and data processing* (All-Russian Research Institute for Hydrometeorological Information – World Data Centre, Obninsk, Russia, 2013)
6. M.A. Lokoshchenko, E.A. Yavlyaeva, H.-J. Kirtzel, Meteorol. Z., **18**, 321-330 (2009)
7. *The METEK radio acoustic sounding system* (METEK GmbH, Elmshorn, Germany, 2013)

8. F.F. Bryukhan, A.Yu. Vinogradov, A.A. Lavrusevich, At. Energ., **118**, 365-368 (2015)
9. O.A. Alduchov, A.F. Bryukhan, At. Energ., **115**, 53-57 (2013)
10. *Generic models for use in assessing the impact of discharges of radioactive substances to the environment: IAEA safety report no. 19* (IAEA, Vienna, 2001)
11. B. Hennemuth, G. Peters, H.-J. Kirtzel, Atmos. Meas. Tech., **5**, 1399-1408 (2012)
12. F.F. Bryukhan, R.D. Diab, J. Appl. Meteorol., **34**, 2565-2571 (1995)
13. S. Lang, E. McKeogh, Remote Sens., **3**, 1871-1901 (2011)
14. S. Boluriaan, P. Morris, AIAA J., **39**, 1097-1105 (2001)