# Challenges and Innovations in Geotechnics

Editor: Askar Zhussupbekov

CRC Press
Taylor & Francis Group
A BALKEMA BOOK

*Challenges and Innovations in Geotechnics – Zhussupbekov (Ed.)*
*© 2016 Taylor & Francis Group, London, ISBN 978-1-138-03007-7*

# Table of contents

*Challenges and Innovations in Geotechnics – Zhussupbekov (Ed.)*
*© 2016 Taylor & Francis Group, London, ISBN 978-1-138-03007-7*

# Evaluation of wind power unit reliability according to the results of field studies on the example of Ereymentau wind power station

D.K. Orazova, A.Zh. Zhussupbekov, R.E. Lukpanov & S.B. Yenkebayev
*Department of Civil Engineering, Eurasian National University, Astana, Kazakhstan*

ABSTRACT: This paper includes the analysis of vibrational effect from the tower block to the foundation of the wind generating unit of Ereymentau WPS. The paper shows results of vibromonitoring of wind power tower (WPT). The analysis of vibrating influence from the tower fluctuating load on WPU foundation had been made by the results of in-situ monitoring. The results of research are presented in diagram dependence of vibrating characteristics (frequency, amplitude, acceleration) from wind pressure intensity. There was given an extrapolation of potential efforts arising in the foundation at maximum wind load in that region. Plaxis 2D software program shows the calculation of vibration impacts corresponding to the foundation of wind power unit (WPU) from the tower.

## 1 INTRODUCTION

Wind power is the most dynamically developing type of renewable energy sources. Having studied the energy potential of wind in Kazakhstan, the Government of the Republic of Kazakhstan together with the UN development Program "Kazakhstan is the initiative of the development of wind power market" has resolved that the Ereymentau district of Akmola region is the most perspective area for the construction of wind power stations [1].

The first steps in the Program realization were taken in Ereymentau district of Akmola region.

Within the context of an upcoming exhibition "EXPO-2017" in Astana it is planned to provide power supply of the exhibition facilities by using the energy of Ereymentau WPS.

Figure 1. Current Ereymentau WPS.

## 2 CLIMATIC AND HYDROGEOLOGICAL CONDITIONS OF THE SITE

Annual measurements of speed and direction of wind were made at the site within the context of UNDP project on wind power. Measurements were performed in accordance with international standards in the field of measuring wind speed in order to estimate wind potential (IEA/IEC) [2].

The distribution of wind speed and Weibull parameters at the height of 51 m (the axis of the gondola) for the site of Ereymentau WPS are shown in Figure 2.

According to the results of wind pressure measurements the diagram of seasonal distribution of wind speed was made. It demonstrates the changes in the wind flow speed by month in relation to average annual wind speed (Figure 3).

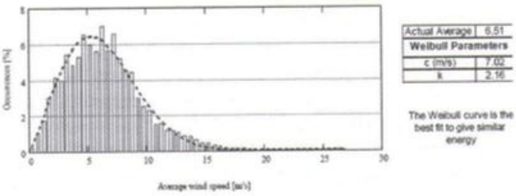



Figure 2. Distribution of wind speed and Weibull parameters at the height of 51 m.

The geological structure of this territory consists of sedimentary and metamorphic rocks of the proterozoic and the paleozoic broken by intrusions in the north–eastern part of the city, and covered by eluvial–deluvial quaternary sediments represented by clays (Figure 4).

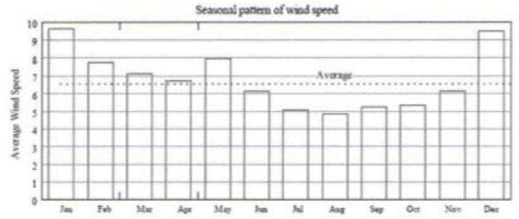



Figure 3. Monthly average wind speed at the height of 50 m.

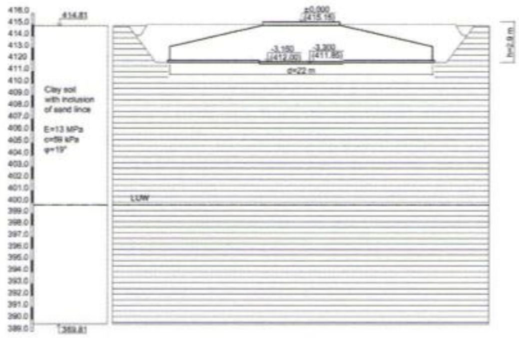



Figure 4. Geological section of the site.

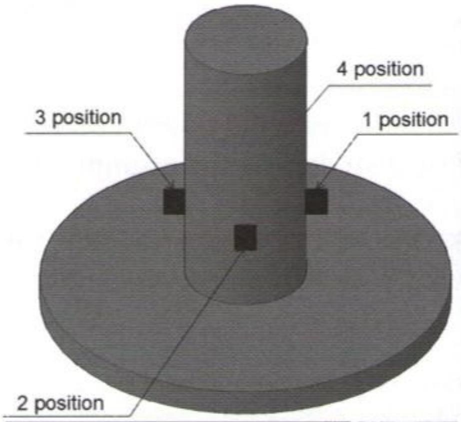
## 3 THE PROCEDURE OF VARIATIONS AND VIBRATIONS MEASURING WITH THE HELP OF VIBRA PROFOUND INDICATOR

The field studies and measuring vibrational effect on WGU foundation were made with the help of VIBRA Profound indicators. These instruments allow defining the speed, acceleration, vibration frequency and foundation displacement caused by wind pressure. The instrument system meets national and international standards SBR 2002, DIN 4150 and DIN 45669.

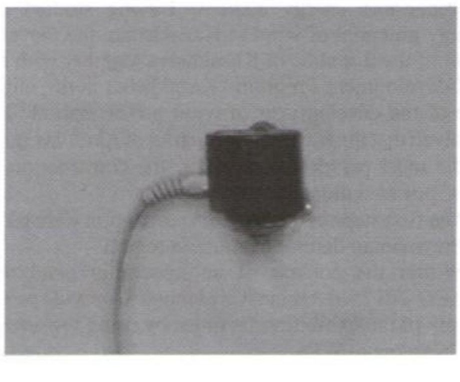
The source of vibration is the WPU tower located on a reinforced concrete foundation with a thickness of 2.9 m and a diameter of 22 m. Fluctuations caused by the tower, are passed to the ground base through the foundation.

Vibration loads from the tower to the foundation were measured by sensors with the help of VIBRA Profound device. Movements are recorded on the WPU tower (Figure 5). Intermediary measurements were counted every 10 seconds.

Vibration impact measurements were made at the Ereymentau site, from August, 26 to September, 27 2015. It took a month to make all the measurements. During a month there were impermanent wind speeds. Control points data was obtained according to the diagrams of the device. The relationship between wind pressure and vibration impacts on the WPU foundation from the tower was obtained after data analyzing. The method of extrapolation can allow measuring the impact on the foundation at a maximum wind speed of 25 m/s.




a)



b)


Figure 5. The location and the sensor measurements of vibrations: a) the location of the sensor on the tower wind turbine, b) sensor readings maximum displacements of the tower wind turbine.

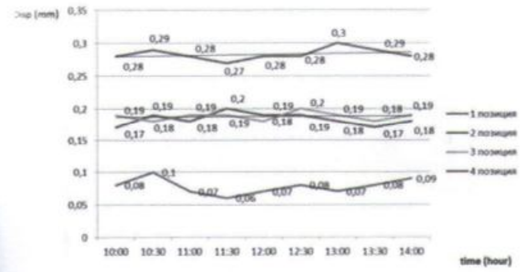



Figure 6. Graph of dependence of displacement and time.

With the help of the instrument we got the diagram of dependence of foundation absolute displacements and the time in this area (Figure 6). The diagram shows the maximum values of displacements for each position. The maximum values of displacements for the 1 position are 0,1 mm, the maximum values of displacements for the 2 and 3 positions are 0,2 mm, and 0,3 mm – for the 4 position, at the maximum wind pressure of 4,75 m/s.

The measurement results of vibration shown in the graphs of dependence of displacements, accelerations, frequencies of vibration, velocity of vibration from wind speed (Figure 7).

## 4 DYNAMIC ANALYSIS OF WIND TURBINES ON AN ELASTIC-PLASTIC FOUNDATION

PLAXIS 2D allows modeling the interaction between soil and construction. The influence of vibration work on the soil on which it is installed was considered.

The dimensions of the soil mass are determined based on the computation of compressible stratum, represented by a clay layer of 60 m. Soil surface is set at the point $y = 0$. The foundation is represented by clay, which is considered here as an elastic-plastic material. A dataset is formed by selecting the *soil* type and *interface*, according to the information given in Table 1. Dynamic stiffness of soil is significantly higher than its static stiffness, as dynamic loading is usually rapid and it results in ultra-small deformations.

Material data set for footing according to the information given in Table 2.

A distributed load is applied to the foundation, as well as a horizontal force and a concentrated moment for modeling the wind turbine weight, and fluctuations that it causes. The geometric model is shown in Figure 8.

Figure 9 shows the deformed mesh of the foundation.

Figures 10, 11, 12 show the results of the accelerations, the results velocity of vibration values and the diagram of the dependence of vertical displacement on time.

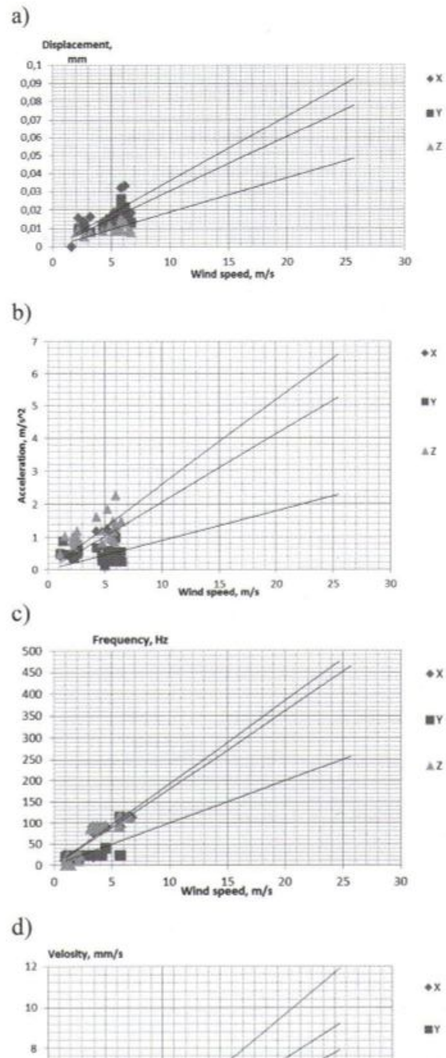



Figure 7. Graphs of dependence of displacements, accelerations, frequencies of vibration, velocity of vibration from wind speed: a) graphs of dependence of displacements from wind speed, b) graphs of dependence frequencies of vibration from wind speed, c) graphs of dependence of accelerations from wind speed, d) graphs of dependence of velocity of vibration from wind speed.

## 5 CONCLUSION

According to the measurement results the prognosis of vibration parameters of wind turbine foundation from wind pressure was made.

Table 1. Material properties of the subsoil.

| Parameter | Name | Value | Unit |
|---|---|---|---|
| General | | | |
| Material model | Model | Mohr – Coulomb | – |
| Type of material behavior | Type | Drained | |
| Soil unit weight above phreatic level | $\gamma_{unsat}$ | 16 | kN/m$^3$ |
| Soil unit weight below phreatic level | $\gamma_{sat}$ | 18 | kN/m$^3$ |
| Parameters | | | |
| Young's modulus (constant) | E′ | 13*10$^4$ | kN/m$^2$ |
| Poisson's ratio | ν′ | 0,38 | |
| Initial | | | – |
| $K_o$ determination | – | Automatic | – |
| Lateral earth pressure coefficient | $K_{o,x}$ | 0,674 | – |

Table 2. Material properties of the footing.

| Parameter | Name | Value | Unit |
|---|---|---|---|
| General | | | |
| Material model | Model | Linear elastic | – |
| Type of material behavior | Type | Non–porous | – |
| Soil unit weight above phreatic level | $\gamma_{unsat}$ | 24 | kH/m$^3$ |
| Parameters | | | |
| Young's modulus (constant) | E′ | 30*10$^6$ | kH/m$^2$ |
| Poisson's ratio | ν′ | 0,2 | |
| Initial | | | – |
| $K_o$ determination | – | Automatic | – |
| Lateral earth pressure coefficient | $K_{o,x}$ | 1 | – |

Figure 8. Geometric model of the foundation.

Maximum values of the parameters at the maximum wind pressure in this region are:

1) Maximum displacement on X = 0,09 mm, Y = 0,076 mm, Z = 0,048 mm;
2) Maximum acceleration on X = 5,14 m/s$^2$, Y = 2,24 m/s$^2$, Z = 6,48 m/s$^2$;
3) Maximum frequencies of vibration on X = 450 Hz, Y = 200 Hz, Z = 480 Hz;
4) Maximum velocity of vibration on X = 7,8 mm/s, Y = 9 mm/s, Z = 11,8 mm/s.

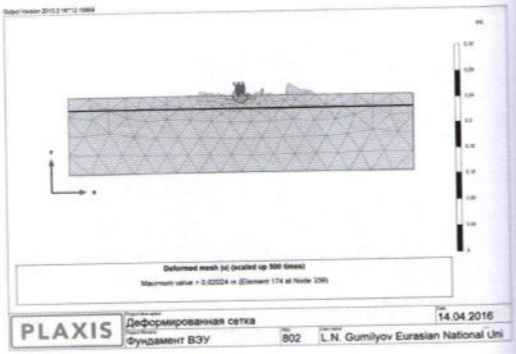



Figure 9. Deformed mesh of the foundation.

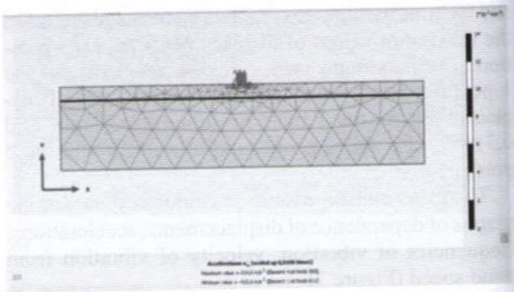


Figure 10. The results of the accelerations.

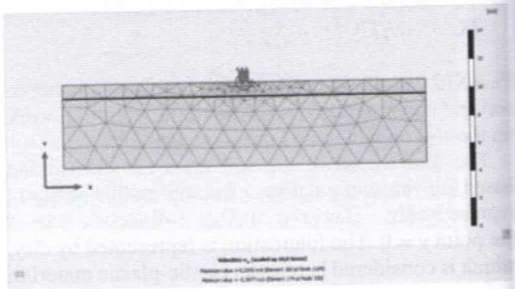


Figure 11. The results velocity of vibration values.

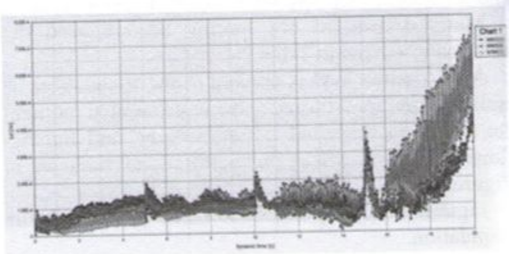


Figure 12. The diagram of the dependence of vertical displacement on time.

...ained vibration impacts from the tower to the ...on under maximum wind pressure were inte... Plaxis 2D software program. Having applied ... and dynamic loads in the program we got the dis...ment with a certain frequency and acceleration, ... vibrations speed.

...e diagram of the dependence of vertical displace... on time shows that these displacements do not ... a limit value for WPU foundations [3].

## ...EFERENCES


...tional program of wind energy development until 2015 with the perspective till 2024 (project) Almaty//Astana. – 2007, 3–5.

Project of the Government of Kazakhstan and the Development Program of the United Nations Organization "Kazakhstan – Initiative of the Development of Wind Power Engineering Market", the wind power plant near Ereymentau city, Pre-investing research//Almaty. – 2008, 7–9.

DIN 45669. Human exposure to vibration in buildings, Germany, 1995–2006, p. 8.