Technical and economical comparing of different wind power unit foundations on geological conditions of Ereymentau city

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ABSTRACT

Wind power engineering 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 in association with the Development Program of the United Nations Organization "Kazakhstan - Initiative of the Development of Wind Power Engineering Market" defined Ereymentau district of Akmola region as the most future-oriented place for the construction of wind power plants. This article reveals the technical and economic comparing of types of foundations of wind power unit (WPU) in hydrogeological conditions of Ereymentau district.

Keywords: alternative energy, wind turbines, piled raft foundation, slab foundation, Plaxis 2D.

1 INTRODUCTION

The Project represents the wind farm with the capacity of 50 MW located in Akmola region to the south-east from Ereymentau city, about 130 km to the east from Astana. The project is the second wind farm of SGE company in Ereymentau from Pre-investing research (2008) and represents the second phase of the project provided for increasing wind energy power in Ereymentau district up to 300 MW. The wind farm is located in the south-east of the Ereymentau city about 2 km from the city center; the nearest residential building is located at a distance of 500-600 m away from the wind turbine.

2 DESCRIPTION OF THE OBJECT

Ereymentau is located in a zone of high wind loads, and this makes it possible to use it for the production of electric power in a large scale

This article represents two sites near Ereymentau for setting of wind power plants according National program of wind energy development (2007).

Electric WPU with the capacity of 2MW (WTU 2.0) represents 3 blade wind oriented turbine with variable rotating speed (Fig.1). WPU meets the requirements of IEC 61400-1 Standard, it is projected according to European technical regulations 2006/42/EG.

Fig. 1. Slab foundation in Ereymentau city

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Geological conditions. The construction site is located on the undulating foothill plain which has the general slope to the north.

The geological structure of this territory has the sedimentary and metamorphic rocks of the Proterozoic and Paleozoic era, which are broken by intrusions in north-east part of the city and covered with eluvia-diluvia quaternary deposits, presented by clay loams, sand loams and clays with land waste and breakstone, clay and clay loam saprolites, breakstone-land waste and land waste-breakstone soils with sandy and clay loam filler.

Fig. 2 shows the engineering and geological section on the sites of wind power unit.

Clay loam is the bearing layer for the slab foundation, breakstone-land waste is for the piled raft foundation.

3 BASIC WORK SCOPE OF THE FOUNDATION CONSTRUCTION

After calculating and designing according Technical Norms and Regulations (1987) of two types of foundations their technical and economic comparing was made.

For this purpose basic work scope of foundation construction for each type and their costs were calculated, the results are shown in the sheet according to the form of Tab. 1.

Tab. 1 shows the calculations of work scope and the costs in accordance with the Fig. 3 for the slab foundation (a) and the piled raft foundation (b).
Table 1. Comparing of types of slab and piled raft foundations.

| №  | Work subject                                                                 | Scope                  | Cost, $  | Scope                  | Cost, $  |
|----|-----------------------------------------------------------------------------|------------------------|----------|------------------------|----------|
| 1  | The planning of sites by bulldozers with the capacity of 79 (108) kW (h.p.) | 1384,7 m²             | 10       | 754,4 m²               | 2        |
| 2  | 2 group soil excavation to the disposal area, for machines, as well as handy excavation | 2241,2 m³             | 3500     | 356,34 m³              | 160      |
| 3  | Dipping of ferroconcrete into the soils of 2 group by the diesel pile hammer | -                     | -        | 7,5 m³                 | 700      |
| 4  | Solid piles of square section with the length up to 8m                       | -                     | -        | 84m                    | 2620     |
| 5  | The structure of breakstone ground for foundation                           | -                     | -        | 14,2 m³                | 800      |
| 6  | Horizontal cement waterproofing with liquid glass of walls, foundations      | 380 m²                | 1800     | -                      | -        |
| 7  | The structure of foundation mattress                                        | 96,7 m³               | 15637    | 18,9 m³                | 3100     |
| 8  | Reinforcement work pieces not arranged in frameworks and grids: periodic profile steel of A-III class, d 8 mm (d 20-22 mm) | 1,58 t (80,06 t)      | 1750     | 0,309 t (14,17 t)      | 340      |
| 9  | Heavy concrete of class 1. B15 (M-200) 2. B45 (M-600) 3. B50 (M-600)       | 0,05 m³               | 6        | 0,02 m³                | 3        |
|    |                                                                             | 0,007 m³              | 1        | 0,05 m³                | 8        |
|    |                                                                             | 0,267 m³              | 44       | -                      | -        |
| 10 | The structure of ferroconcrete plain foundation plates                       | 625,3 m³              | 112517   | 195 m³                 | 36600    |
| 11 | Backfilling of trenches and pits by bulldozers                               | 581,9 m³              | 30       | 133,28 m³              | 7        |
| 12 | Waterproofing (bitumen primer) and lubricating bitumen in 2 layers on the flattened surface | 892,73 m³             | 7531     | 168,84 m³              | 1557     |
|    | Total in current prices by 01/01/2014:                                       | 224 500 $             | 60 100 $ |                        |          |

The basic work scope in foundations construction includes the following: the planning of construction site, soil excavation, foundations structure. The total cost of the work was as follows: 224 500 $ for the slab foundation, 60 100 $ for the piled raft foundation.

4 CALCULATION OF THE DEFORMATIONS OF FOUNDATIONS ON THE PC PLAXIS 2D

Calculation of the slab and piled raft foundation is made in an axisymmetric formulation of the problem using Mohr-Coulomb model. The initial data for calculation of the foundation are shown below:

The initial data on Plaxis 2D

| Clay loam | Coordinates: | | | |
|-----------|--------------|---|---|---|
| №6        | x            | y        | | | |
| γ<sub>unsat</sub> = 18кN/m3 | 17,1, (+0,92) | | | |
| γ<sub>sat</sub> = 20кN/m3 | 5,5, 18,02 | | | |
| E=22000 MPa | 2,25, 19,42 | | | |
| ν= 0,4 | 2,25, 20 | | | |
| c=69 | 0, 20 | | | |
| φ=27 | | | | |
| | | | | |
| Land waste | | | | |
| №4 | | | | |
| γ<sub>unsat</sub> = 2.1кN/m3 | | | | |
| γ<sub>sat</sub> = 2,1кN/m3 | 0, 20 | | | |
| E=28000 MPa | | | | |
| ν= 0,3 | | | | |
| linear elastic (c and φ are absent) | | | | |

Fig. 4. Calculation scheme of the foundations
5 CONCLUSIONS

Displacement – load diagram shows that the displacement of the point A (edge point) = 40 mm and B (middle point) = 8 mm is for the slab foundation, the displacement of the point C (edge point) = 19 mm and D (middle point) = 4 mm is for the piled raft foundation.

Comparing the types of slab and piled raft foundations we see that the type of the slab foundation is much more expensive in spite of the same design condition. We recommend using a piled raft foundation and accept a piled raft foundation as more economical and reliable type of foundation for the future development of this project.

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