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State of Art For Design of Foundation For Wind Energy Converteter

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Abstract— **Most land-based wind turbines on strong and stiff soils, but probably in the future wind turbines will have to be built also on soils with less good properties. The ordinary and fairly simple foundation method with a concrete slab with larger area, may be abandoned since it can give you too large differential settlement.**

The Foundations for onshore wind turbines where both the more conventional method with a large concrete slab are investigated, but also alternative foundation methods are studied, mainly piled foundations.

Design procedure consists of both manual calculations and numerical analysis. A case study of an 80 meter high wind turbine with realistic loads is presented. The study includes geotechnical and structural design for three different soil profiles, in which three different foundation methods are used.

Keywords— Foundation, Wind turbines, Loads

1. INTRODUCTION

The access to energy is very important matter in modern society, but even more important is how the energy is provided. There is almost unlimited ways of how to provide energy and each method has got their own benefits and disadvantages. The method should be efficient and in addition not affect the environment

in a bad manner, where the latter is playing a very important role for energy production today.

One of the bigger challenges for today's society is the change from non-renewable energy sources, such as fossil fuel consumption to renewable sources such as wind power. Today, almost 70% of India's energy originates from fossil fuels and about 2% only comes

From wind power. The situation is not specific for India, but more of a trend valid for most countries.

I.

2. METHODS OF FOUNDATION FOR WIND TURBINES

1. Spread Foundation
2. Shallow Foundation
3. Gravity Foundation
4. Piled Foundation
5. Piling to bedrock
6. Piled-raft Foundation

II. METHODOLOGY OF DESIGN

For one specific wind power plant with specified load data, it can be interesting to compare different types of foundation methods for different geotechnical conditions. The most appropriate methods for each case will be designed. Three different cases are represented; the first one is a moraine soil with good strength and high stiffness, the second and third consist of clayey soil, where the last one has got great depth to the bedrock and the second not great depth. In all three cases, the soil is overlaid by a 3 m thick fill material with high permeability (low capillary suction).

III. LOADS

There are three different sets of loads that are given; ultimate limit state (ULS) loads, serviceability limit state (SLS) loads and the fatigue analysis loads.

Regarding the fatigue loads they are calculated in means of a rain flow count algorithm which often is used in fatigue analysis. This algorithm transforms a spectrum with loads to an equivalent simpler set of loads [35]. From this analysis one get mean values of the loads together with an interval.

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This interval gives you characteristic values for the forces; one minimum- and one maximum value. The width given is calculated for a stress exponent with a value of 7, which is used in the fatigue design. The number of cycles the loads are given for is 10 million.

IV. GENERAL ASPECTS IN THE CHOICE OF FOUNDATION METHOD

V.

The choice of foundation method is dependent on many parameters, and it is hard to decide when a specific method is the most appropriate. Generally, it is the most cost-efficient solution that is chosen, given that the safety can be granted. When calculating a budget for the construction of a foundation, there are almost unlimited numbers of costs that have to be considered. Though the factors listed here are of major importance:

- *The site availability. Is the site very remote? Is there a road leading to the site? Is it necessary to improve the strength of the road?*
- *The amount of material required. The volume of the concrete, the amount of reinforcement, the number of piles, the pile material, etc.*
- *- The designing work. Are the construction documents time-consuming to create? Do the designers have the knowledge and tools that are required?*
- *The construction work. Is extensive excavation work necessary? Is the design optimized and fast to construct? Does the construction work affect the environment?*

The primary focus of this thesis is to come out with cost-effective solutions for the foundation design for different types of soil conditions. When the designer starts his work, the site is specified and a geotechnical investigation is already performed. The wind turbine with its embedded ring and the loads for the actual case is obtained from the manufacturer of the turbine. With the help of this information, it is up to the designers to carry out necessary construction documents for the contractor to build after.

The geotechnical investigation from the site is providing information about the soil layer sequence, the distance to the bedrock, the strength and stiffness parameters of the soil layers, the groundwater level and its variation. This information is valuable when deciding the foundation level and if piling is appropriate.

If the soil is strong and stiff and the groundwater level is at great depth, a spread foundation is preferred. This is the simplest foundation method in many respects; it is a well-proved foundation that is easy to construct and quite easy to design. It is generally also a cheap method as no piling work is necessary.

If the soil parameters are somewhat worse, the sufficient area of a spread foundation is quite big to keep the ground pressure below the soil's capacity. The required amount of concrete is getting very big as the volume increases with the squared distance, and another foundation method may be more cost-efficient. There are several possible alternatives besides the spread foundations then.

One good solution can be to foot the foundation deeper in the ground. The capacity of the ground is better at greater depth, and in addition, the width of the foundation can be decreased thanks to the bigger vertical load from the overlaying soil. This will result in a smaller eccentricity of the load. One disadvantage of this solution is the major excavation work this requires. If the site is remote and the excavated soil cannot be used as refilling material, this may be an expensive method.

Another solution is to perform soil improvements by exchanging the soil, compacting the soil, or adding some strength to the soil with the help of lime/cement columns or grout. These methods are expensive, but can yet be realistic if the soil quality is poor.

If the soil layer sequence shows that a strong and stiff layer is at reasonable depth, it can be a good solution to drive piles to this layer. The piles are then functioning as toe-bearing piles, and soil above the strong layer is not carrying any load. To ensure that the piles are not buckling, the subgrade modulus of the soil cannot be too low. The same is valid for piles driven to the bedrock. A benefit with the bedrock-driven piles is that the piles can be anchored in the bedrock to handle tension forces, though this requires very solid and strong bedrock.

If the bedrock is at great depth and the soil hasn't got enough stiffness for a reasonable big spread foundation, it can be a good method to install cohesion piles. To reduce the number of piles and the pile length, a calculation model which assumes that both the plate and the piles are bearing load, can be of interest. It is then necessary that the designers have highly reliable information about the stiffness parameters of the ground to model this in the right way. Modelling the soil too stiff may result in too big loads in the piles, and a failure can occur.

Three different foundation methods are concerned. The first one, the spread foundation, is the obvious choice for the conditions of the site. The soil is strong and stiff, and the groundwater is at a reasonable depth. If the groundwater level is changing very much, it could be appropriate to set the foundation level at the ground level to minimize the risk of lifting forces from a high groundwater level. Though for a more shallow footing, it would be necessary to put soil above the foundation to get sufficient weight to keep the eccentricity low.

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For case 2, with weak soil and bad stiffness, a spread foundation would result in too big settlements if the soil body wouldn't collapse first. As the bedrock is at a reasonable depth, it is quite easy piling work. By driving the piles to the bedrock, one gives the piles high capacity, because it's only the structural capacity that has to be considered. This capacity is often higher than the bearing capacity from the soil would be for a pile installed without the toe-bearing. For this site, conditions would also suit the foundation in the Ruukki case, described in section 1.7, to be suitable. By anchoring the piles in the bedrock, a much smaller plate can be used due to the high tension forces the piles can carry. In the Ruukki case, only 8 large piles were used with extremely high capacity. The maximum pile loads became in that case 5.8 MN in compression and 2.5 MN in tension.

The site conditions apparent in case 3 are not very well suited for a foundation with this extreme load condition. Anyhow, there are a few options for foundations for this site, where the one chosen, namely a spread foundation with cohesion piles, is one of them. Another method could be to perform soil improvements primarily to get a more stiff soil to reduce the settlements. The methods described in Chapter 3.2 could then be applicable. The method chosen for this, with cohesion piles and a wide spread plate, is benefited if the calculation model assumes that both the plate and the piles are bearing load. This should in general result in a more cost-efficient solution because of the reduced piling length this should generate.

VI. CONCLUSION

Case 1 above is no doubt the cheapest method as it doesn't involve any pile work. The required reinforcement is a little higher than for the other cases, but the extra amount is however a relatively small cost in relation to the pile work.

The design is quite easy and straightforward to perform. Most of the calculation can be made manually, but the settlement calculation is preferred to do numerically as it involves a very big eccentricity of the load which will cause a rotating motion of the foundation in the soil.

A conclusion is that if the ground allows the big pressure that will arise, this type of foundation should be chosen.

Case 2 gives a relatively little total piling length and is a good method if the distance to the bedrock is reasonable. The amount of reinforcement is quite big as it requires more reinforcement at the parts near the perimeter of the foundation due to the big point loads from the piles. The settlements for this type of foundation are very small and the whole structure is very stiff.

The geotechnical design is very straightforward and the level of uncertainty is fairly low, as it only includes the structural capacity of the piles, given that the bedrock is strong and stiff. This method assumes no movement in the piles and to ensure that this actually is the case, it has to be verified that the piles actually are standing on the bedrock (or the strong soil layer). The pile installation work is then of major importance for this type of foundation.

Case 3 resulted in a very large total piling length, and in reality, this foundation would probably not have been constructed as it would result in a too expensive foundation. The question is whether the geotechnical design is performed properly or not. In this thesis, a two-dimensional model is created for the geotechnical design with the piles modeled as plate elements. The number of piles is determining the stiffness of the plate elements, but in reality, it is the surface area of the piles that are significant; the more piles the bigger surface area and the smaller settlements. This cannot be modeled properly in a 2-dimensional model. A 3-dimensional model would probably have resulted in a more trustworthy design giving lower settlements. As a consequence, the amount of piles, and the pile length could be lowered.

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