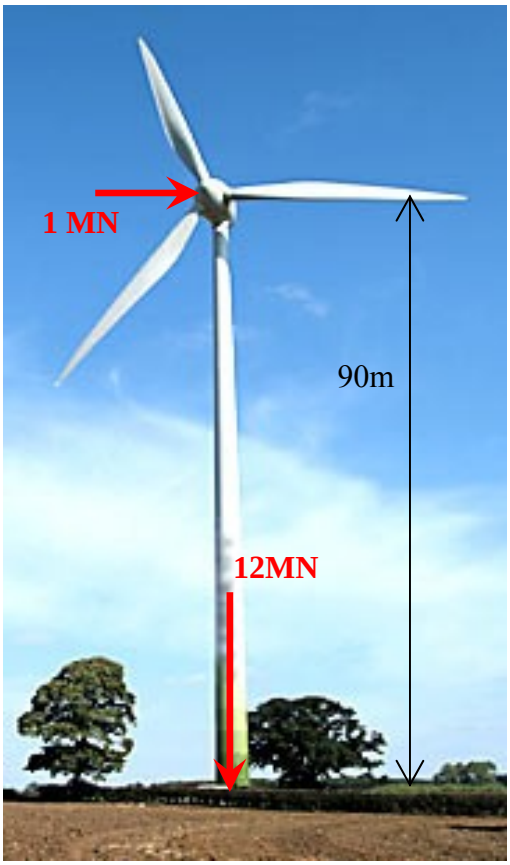
CE 462 – Fall'15 TERM PROJECT

Due date: January 22
Late penalty: (submission date – 23Jan)^2



Task
Design the foundation of a 90m tall wind turbine. Due to large moments, piles are necessary.

Forces
- The wind turbine weighs 12 MN in total.
- The pile cap will be 1 m thick reinforced concrete. Weight of the pile cap is **not included** in the vertical load given above, so you have to calculate and add its weight to your total vertical load. Edge of the outermost row of piles must be at least D/2 from the edge of pile cap, where D is diameter of one pile.
- Under extreme wind conditions, the resultant aerodynamic force is 1 MN. This force can be assumed to act at the nacelle (90 m high), but it can act in any horizontal direction.

Subsurface Conditions
An additional file named "15-TPsoils.pdf" is uploaded on the course website. It gives descriptions and engineering parameters of 12 different real soils. It also includes the soil layers and groundwater level given separately for each group.

Design Considerations
- There aren't any local companies with pile driving rigs in this region, so the design will be bored and cast in place reinforced concrete piles.
- Standard auger diameters are 30, 45, 65, 80, 100, 120, 160, 200 cm. All piles in your design should have the same diameter.
- Your design should aim to minimize the cost (but don't spend too much time in trying countless different designs in search of the minimum cost solution). Cost/length of piles increase with diameter, as well as length. To calculate the total cost (TL) of a single pile with diameter D (m) and length L (m), you can use the following equations:

$$\text{total cost of one pile} = 160.D^2.L \text{ (materials)} + 40.D^{0.5}.L^{1.2} \text{ (construction)}$$

- Similarly, the cost of the pile cap can be calculated as 250xArea.

General Assumptions
Assume all deformations are within the linearly elastic range of soil behavior.
Assume the pile cap is rigid.
Assume changes in the quantity of steel reinforcement in the cap or the piles don't affect the weight significantly, and overall unit weight of reinforced concrete is 25 kN/m^3.
Assume C30 (f_{cd} = 20 MPa) for concrete and St420 (BÇ-III) (f_{yd} = 365 MPa) for steel strength.

DESIGN CRITERIA

Vertical Load Bearing Capacity Criteria

- Load on each pile must be calculated. Vertical load can be distributed by equating settlements of piles (because pile cap is rigid) like in the example that was done during the group settlement lecture. Then you can superpose these loads with the loads due to moment. *(Hint: Doing the calculations related to settlement criteria together with this will be better)*
- Load on each pile must be less than its allowable vertical load capacity. Your design must satisfy both overall and partial (tip and skin) factors of safety. Use the following factors from Eurocode7 Design Approach 1 Combination 2: 1.3 for skin resistance, 1.6 for tip resistance, 1.5 for overall compression capacity, 1.6 for overall tension capacity.
- Group action must be considered. The factors of safety for a single pile are valid for block failure analysis as well. You can have the design moment balanced by soil pressure variation under the tip of the block, in the same way as shallow foundations carry moments (see CE366 notes).

Settlement Criteria

- Calculate settlement of a single pile per unit vertical load, and report its inverse as the vertical stiffness at pile head.
- Allowable average settlement is 25mm. Results from elastic superposition and imaginary footing methods must independently satisfy this criterion.
- Calculate rotation of the pile cap due to moments. Allowable rotation is 1/1000.

Horizontal Load Capacity Criteria

- Calculate horizontal load capacity of one pile.
- Your design must be able to carry horizontal loads with a factor of safety of 2.
- Group action must be considered.
- Horizontal load on each pile must be calculated. Horizontal load can be distributed by equating deflection of piles at the cap. *(Hint: Doing the calculations related to deflection criteria together with this will be better)*

Horizontal Deflection Criteria

- Calculate deflection of a single pile, at the cap, per unit vertical load, and report its inverse as the horizontal stiffness at pile head.
- Allowable horizontal movement of the pile cap is 25mm.
- Plot deflection and moments along the length of the pile that has the largest horizontal load.

Pile Criteria

- Piles must not buckle under 3 x design vertical load.
- Pile section and longitudinal reinforcements must be sufficient to take (design vertical load) x 1 and (maximum moment plotted in the previous section) x1.5. You may quickly verify this by determining longitudinal reinforcement with the help of the interaction diagrams given in Uğur Ersoy's Reinforced Concrete book, and checking if the reinforcement fits into the section.
- Quantity of shear reinforcement that can take the maximum shear (horizontal loads times factor of safety of 2) must be determined.

Report must include:

- Cover page, with group number and names of all group members.
- Table of contents.
- List of symbols.
- Figure showing idealized soil profile, and assumed soil properties.
- Description of final design and its Autocad drawing – 3D or rendered drawing are not necessary. You must include (i) top view of pile layout, (ii) side view of the pile foundation that also shows soil layers and (iii) top and side views of reinforcement in one pile.
- Calculations showing that your design satisfies each item listed under each criteria (vertical load, settlement, horizontal, pile). If values are read from tables and figures in the course reference compilation, page numbers must be cited. This will be the bulk of your report. Note that you don't have to follow the order of criteria given above.
- A discussion of which criteria (among the 9 criteria underlined above) are most critical for the design. This can be done by presenting a table of criteria and calculation results for the selected design (for example, it would list "average settlement – allowable is 25 mm – calculated settlement is 17 mm – moderately critical")
- Cost calculation of your design.
- Based on the most critical criteria, suggest an alternative (it must be a reasonable design, perhaps another configuration you have tried before reaching your final design). You don't have to show all calculations of the alternative at the same detail as the original one, a 1-2 page summary of results is enough. Calculate cost for this altenative design and show that your design is more economical.
- List of references (if used).