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**Network-as-a-Service Runbook**

***Primer for Construction Guidelines for Tower Foundations and Anchors***

**<NaaS Operator’s Name>**

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*<Release Date>*

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# Document Control

- Revision Control sheet allows to maintain a record of changes made on the document.

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Table 1. Revision History

# Introduction

NaaS Operator will usually rely on Site Construction Vendors for the design of the foundations which are required for Towers and Towers’ anchors. The objective of this Primer is to provide reference guidelines that can be used to framework design principles for discussions with selected Vendors.

# Foundations and Anchors

The following are reference principles for foundation designs:

* Foundations and anchors for tower and mast structures shall be designed to support the full expected dynamic loads: antennae, feeders, wind loading, etc.
* The design will consider the inputs of the geo-technical investigation findings on soil and wind conditions at the installation site to determine bearing pressures (vertical and horizontal), the suitable foundation type (reinforced concrete blocks, standard pad and column, raft, preset rock anchors or piles), construction materials and installation method.
* Engineers will compute the weight of tower structure, antenna feeders and all associated steel work and then, calculate the effect of wind loads on the total surface.
* Worst case load design condition should always constitute the initial factor of safety against overturning.
* Standard foundation designs should be made for normal soils. It necessary, it may be modified to suit the soil conditions at the specific installation site.
* The following are reference settings used for foundation designs in normal soils (can be used by NaaS Operator to compare against provided parameters supplied by the Construction Vendor):
  + An allowable net vertical bearing capacity of 192kPa
  + An allowable net horizontal pressure of 63kPa per linear meter of depth to a maximum of 192kPa.
  + Unit weight of compacted soil greater than 16 kN/m3
  + Water table is at a depth greater than 2.5m below the surface
  + Coefficient of passive earth pressure greater than 3.2
  + Coefficient of active earth pressure of approximately 0.3
  + Soil with Non acidic properties
  + No organic materials are present in the soil
* Proper soil borings shall be made by competent soil testing specialists and they must go deeper than the probable depth of the foundation to make sure of soil type consistency.
* For guyed towers, borings shall also be taken at all guy locations and at the base per location since conditions can vary widely on the site.
* Pile, raft or specially designed foundations or anchors are to be considered in submerged, marshy or peat soil conditions.
* Foundation drawings:
  + Foundation drawings shall indicate structure reactions, material strengths, dimensions, reinforcing steel and embedded anchorage material type, size and location.
  + If the design is done for normal soil conditions, this will be registered. Every foundation design shall include site soil data as a footnote.
* Foundation designs shall be made and certified by qualified and registered professional engineers.
* A name plate giving details of the designer and the builder will be placed in a clear location at the tower base.

# Types of Foundations

Different foundation types are possible for different structures and soil types. Construction Vendor should specify the type of foundation to be used for each Site.

* Standard Foundation
  + Standard foundations and anchors may be used for construction when actual soil parameters are the same as or exceed normal soil parameters.
  + Geo-technical investigation will verify if the actual site soil parameters are the same as or exceed normal soil parameters. This will be made before standard foundations and anchors are utilized in final designs.
  + Foundations and anchors will be designed for the maximum structure reactions resulting from the anticipated worst loading conditions.
  + If non-standard foundations and anchors are going to be used for construction, the soil parameters recommended by the geo-technical engineer should incorporate a minimum safety factor of 2.0 against ultimate soil strength.
* Raft Foundation
  + To determine the dimensions of the raft, pressure distribution under maximum design loads will be considered to ensure that tensile forces do not develop under a significant part of the raft area.
* Piles
  + Pile foundations are recommended in swamps and peat soils, in order to overcome catastrophic effects of uneven settlement in other types of foundation.
* Drilled Foundations
  + The design and construction of drilled foundations presents certain challenges to Engineers. Consequently, the engineers involved in the design process should consider the following:
    - Foundations can be drilled in any type of soil formation including sandy soils where drilling is however not straight-forward due to the likelihood of hole cave-in.
    - Where drilling is in sandy soil, a casing may be used and pulled out as the concrete is being placed so that the concrete is in contact with the sides of the hole.
    - Alternatively, drilling slurry could be used. The hole is filled with "mud" and as the concrete is pumped into the bottom of the hole, the mud is pumped out at the top. The concrete likewise makes immediate contact with the soil and the foundation provides the support that is required.
* Foundation in Swamps
  + The erection of Guyed tower in swamps can be performed more quickly and efficiently, and less expensively with modified construction techniques and an alternative method for anchoring.
  + This technology, called ‘simple marsh anchor’ method, employs square rods with screw helices at one-meter intervals on the initial three to six meter length.
  + Use of the screw anchors requires only the availability of an auger machine to screw the anchors into the ground thus avoiding the digging of holes, forming, and pouring concrete.
  + The anchors are simply screwed into the ground until a layer of earth is encountered that offers sufficient resistance to achieve the required installation torque.
  + To shorten the depth to which anchors are to be screwed, the use of multiple anchors with load-distributing linkages is recommended.
  + The advantage of this method is the ease with which extensions or additional anchors can later be added if capacity needs to be increased for additional load requirements or for the addition of torque arms.

## Anchors

The following are reference guidelines for the design of anchors in guyed towers.

* Rock Anchors
  + Rock anchors shall be designed to ensure long life and will be treated against corrosion.
  + Pre-stressed rock anchors will have their upper terminating steel work in such a way as to have a steel-to-steel connection between the structure footing and the rock anchor tendon.
  + The upper end termination of rock anchors shall not be encased in concrete but shall be protected against corrosion. This will allow proper checking of the tension in the tendons during the life of the structure.
* Anchor Bolts Template
  + Templates to provide proper anchor bolt orientation during foundation forming will be used to eliminate problems associated with misalignment.
  + Templates shall be precisely fabricated and used in constructing tower foundations in accordance with design specifications.
* A minimum of two anchor stirrups shall be provided around each leg of a tower.