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Communication Tower Foundation Selection Criteria

Introduction

This foundation selection criteria document has been prepared by the Engineering Specialties Group as a resource for public and private entities, who construct, own and manage communication infrastructure. It is our intent that this document be used as a reference during the planning phase of a project, but all communication infrastructure should be implemented under the supervision of a registered professional engineer. We hope you find this resource helpful. Please contact us if you have any questions regarding this information.

Definitions

Self-Supporting Towers

A self-supporting tower is a free-standing tower with three or four legs connected by a latticework of braces. Self-supporting towers can either utilize a single foundation supporting all of the tower legs or individual foundations below each leg. Due to wind loading, lattice tower foundations can experience both vertical loads and horizontal loads. The vertical loads act in both, the upwards and downwards directions, as the tower attempts to overturn. The horizontal or shear loading can act in any direction as the direction of the wind can vary.

Self-Supporting Tower

Guyed Towers

A guy tower is a cable stabilized tower with a central mast surrounded by one or more levels of guy wires. The guys typically extend in three directions from the mast and extend to the ground where the guys are anchored. Guyed towers require separate foundations for the mast and each guy anchor. Due to the weight of the mast structure, the weight of the guy wires and the fact that guys are tensioned during installation, the mast creates a large downward load on its foundation. Additionally, the mast foundation must also be designed to resist horizontal loading caused by wind. The guy anchor foundations are subject to uplift and horizontal loading directed along the guy wire path.

Guyed Tower

Monopole Towers

Monopole tower are simple, single mast, hollow steel pipe towers. A monopole utilizes a single foundation at its base that takes the vertical, horizontal and most importantly, the overturning load of the tower.

Monopole Tower

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Definitions (cont.)

Spread Footer (Mat) Foundations

A spread footer foundation is the most common type of foundation used for self-supporting towers and the mast foundations for guyed towers. A spread footer is simply a large reinforced concrete slab that resists the forces placed on it by mass alone. The weight of the footing is sufficient to resists the uplift forces as well as the overturning and sliding forces of the tower. The downward forces placed on the foundation are spread across its base such that the bearing pressure on the soils below are minimized. It is common for spread footer foundations to have one or more columns, or pedestals, protruding from the top of the slab to support the tower above at ground level. This is generally done to take advantage of the weight of the soil covering the slab.

Spread Footer w/ Pedestals

Drilled Shaft (Caisson) Foundations

Drilled shaft foundations are a common type of foundation used for both self-supporting towers and guyed towers. Typically shafts are placed below each leg of a self-supporting tower or in the case of a guyed tower, below the mast and at each guy anchor location. Drilled shaft foundations are constructed by drilling a hole into the earth, placing reinforcing steel and anchor bolts into the hole and then filling the hole with concrete. Drilled shaft foundations vary in diameter from 1' to more than 4' and lengths can vary greatly depending on soil conditions. Drilled Shaft foundations can be designed to resist vertical loads in one of two ways: 1) The vertical load is transferred to the earth through friction between the soil and the sides of the shaft or 2) The vertical load is transferred to the earth by the end of the shaft bearing on the soil. The soil conditions determine the design methodology. The lateral load capacity of the shaft is determined based on the stiffness of the soil and the length of the shaft.

Drilled Shaft at Guy Mast

Drilled Shaft at Guy Anchor

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Micropile & Rock/Soil Anchor Foundations

Micropile and rock/soil anchor systems are similar in function, but vary in the way they are constructed. Both foundation types are well suited for rocky soils, but can also be utilized on other soil types. Both types of foundation systems are generally used in combination with mat foundations or pile caps at the ground level to connect the small micropiles or anchors to a tower structure.

A micropile is constructed by drilling a small (6" to 12") hole 20' or more into the earth, placing a single threaded rod in the hole and then filling the hole with grout. Grout is a high-strength cement material similar to concrete that utilizes a high percentage of sand rather than the larger rock aggregate used in concrete to improve its ability to flow into small places and to be pumped. Micropiles often include a steel pipe casing at grade level to improve the ability of the pile to resist horizontal loads. The casing generally extends from the top of the pile to 5' or 10' below the surface.

Rock and soil anchors are constructed similarly to micropiles by drilling a small (3" to 6") hole into the earth and placing a single threaded rod in the hole. The depth of the rods can greatly vary in length from 5' to 50'. The rod can be bonded to the soils with a number of methods:

- Grout can be used to bond the rod to the earth. It is common for hollow threaded rods to be used which allows grout to be pumped through the center of the rod into the bottom of the hole.
- In softer soil conditions, the end of the rod can have a pivoting plate attached to it which rotates when a load is placed on the rod, locking the rod in place.
- In hard-rock soil conditions, mechanical anchors can be used to attach the end of the rod to the rock. The mechanical anchors expand when the rod is rotated creating a wedge-effect between the rock and the anchor.

Micropiles have high vertical load capacities and moderate horizontal load capacity. Rock and soil anchors have high pull-out capacities, but no downward or horizontal load capacities. Downward and horizontal load capacities can be generated by combining micropiles and anchors with mat foundations. It is common for both micropiles and anchors to be attached to foundation structures at ground level. Often, multiple micropiles or anchors are placed in close proximity to each other and tied together with a steel or concrete cap. This engages the strength of multiple micropiles or anchors while creating a larger platform at grade level to connect the foundation system to the tower structure. The rods of both micropiles and anchors are often pretensioned to both set the anchor and to also reduce the effect of the cycling vertical loads experienced by structures like communication towers.

Grouped Micropiles w/ Casings

Micropiles Encased in a Pile Cap

Installation of Micropiles

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Foundation System Pros & Cons

The following table describes some of the pros and cons for each foundation type:

	Spread Footer	Drilled Shafts	Micropiles/Anchors
Pros	- Low cost. - Minimal equipment required to construct.	- Minimal site impact. - Requires less concrete than a spread footer. - Well suited for expansive soils.	- Minimal site impact. - Requires very little concrete and grout. - Concrete and grout can easily be batched on site. - Excellent for hard-rock and varying soil conditions. - Excellent for remote locations with poor road access.
Cons	- Foundation is large and has a large impact. - The addition of pedestals reduces the volume of concrete required but increases the depth of the excavation. - Requires a significant volume of concrete. - Concrete must be batched on site for sites with difficult access or remote locations (increases cost).	- Moderate cost. - May not be efficient for hard-rock soils or soils with a mixture of soft soils and boulders. - Requires specialty drilling equipment and expertise. - Generally requires a concrete pump truck. - May requires water for drilling in rock. - Longer construction schedule required.	- High cost. - May not be efficient for soft soils. - Requires specialty drilling equipment and expertise. - Longer construction schedule required.

When is a road too tough for even an all-terrain concrete truck?
You do have options.

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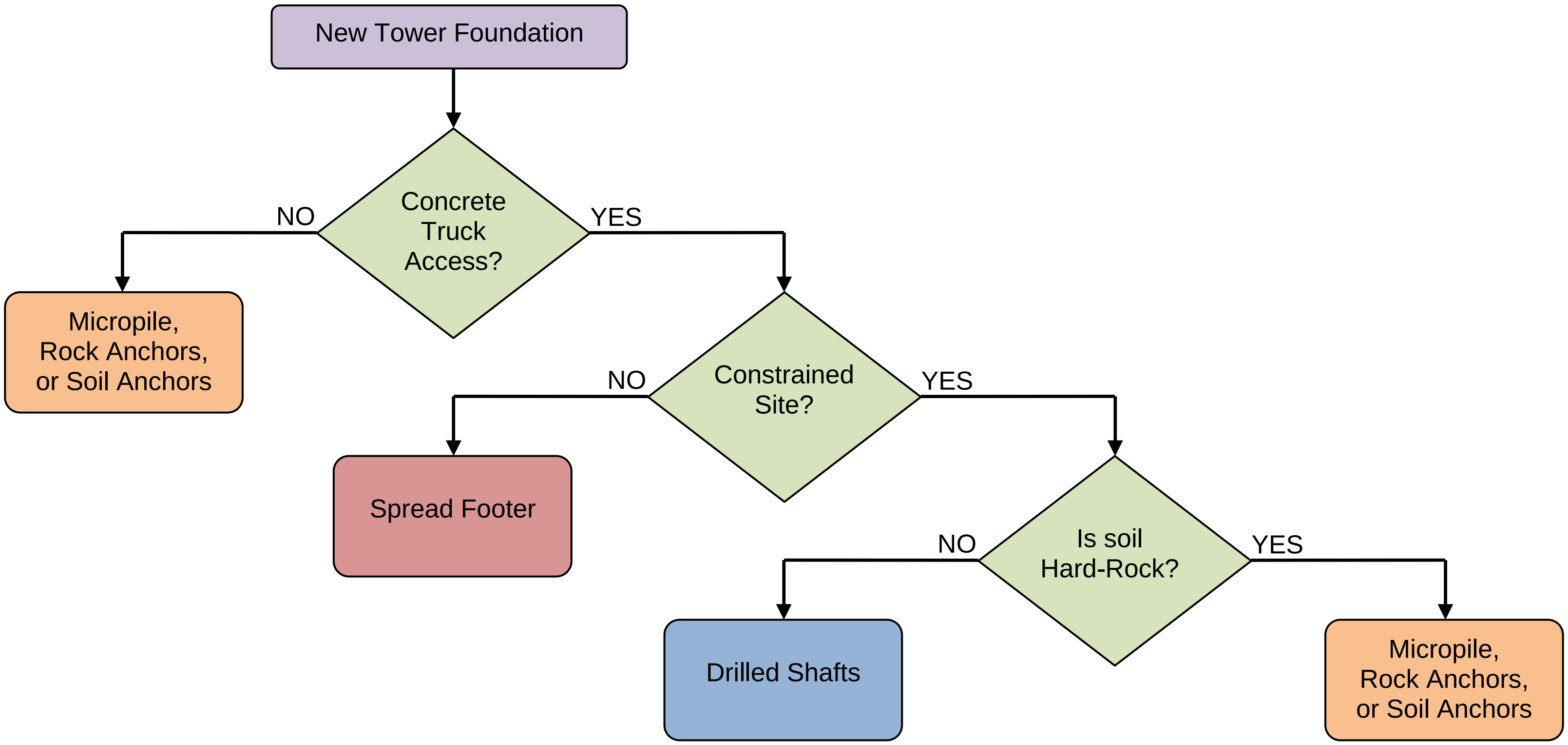
Foundation Selection Decision Matrix



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Geotechnical Investigation Recommendations

Geotechnical investigations are commonly last-minute thoughts during a communication tower design. These studies, generally performed by subcontractors to the tower erector, are often procured at the lowest cost possible. When least cost, not value, is the objective, the geotechnical studies often fail to adequately address the requirements of a project. At a minimum, a responsible geotechnical investigation should be based on the following:

- Knowledge of the proposed structure, foundation type, predicted foundation loads and construction methods.
- Local knowledge and research of the site area and a site visit by a qualified geotechnical investigator.
- Prediction and communication of all geotechnical considerations for the site.

The key to obtaining an appropriate geotechnical investigation resides with communication. The project engineer(s) designing the site and the tower should effectively communicate with the geotechnical firm providing the investigation to convey the nature of the project and the structures that are proposed. Without knowledge of the structure type, foundation type and construction methodology, a geotechnical firm cannot effectively provide geotechnical recommendations. Additionally, every geotechnical study should include a visit to the site by qualified personnel to observe the site conditions and the exploratory testing. In most situations, a minimum of one soil boring is required to accurately understand the soil conditions. Finally, it is important that the project team communicate any changes in the design as the project progresses. The geotechnical recommendations should be modified if the structure type, foundation type or construction methodology change.

Geotechnical Study Specifications

The following list contains the suggested minimum requirements that should be included when preparing a specification for a geotechnical study:

- Review of geologic maps and resources for site area.
- Site observation and observation of testing.
- Assessment of seismic activity.
- Assessment for potential of structure settlement.
- Assessment of potential for landslide.
- Review of proposed structure and construction plans.
- Subsurface soil investigation and testing.
- Assessment of potential for surface fault rupture.
- Assessment of potential for liquefaction.
- Assessment of existence and potential for groundwater.
- Report documenting findings and recommendations including recommendations for temporary construction activities.
- Four-point Wenner Method soil resistivity testing for grounding system design.

Specific Requirements

The following list of requirements applies to the designated foundation type:

Surface Foundations (spread footers)

- Allowable bearing capacity.
- Recommendations for over-excavation and/or soil compaction.
- Coefficient of sliding friction.
- Active and passive soil characteristics.
- Soil unit weight for in-situ fill.

Deep Foundations (micropiles, rock anchors, drilled shafts)

All requirements listed under Surface Foundations, in addition to:

- Ensoft, Inc. Lpile and/or Group soil properties.(sufficient depth)
- Allowable side friction and/or end bearing per soil layer.
- Lateral resistance recommendations.
- Foundation/anchor testing recommendations.
- Construction technique recommendations.

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