Design and Construction of a Telecommunications Tower Foundation Using Micropiles

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ABSTRACT

The design and construction of a self-supported tower (three-legged tower) foundation was performed. An existing tower affected structurally by hurricane Maria is located in a very remote location in Yabucoa, making the replacement of the tower a very challenging project. The replacement of this tower is vital for the reconstruction and re-establishment of the cellular communications in Puerto Rico. The use of micropiles was chosen because a relatively small equipment is needed to construct the micropiles. Also, the amount of material needed to complete the micropiles is small as well. This makes it a very suitable alternative for this very difficult vehicular access project. Cost effectiveness and constructability was also a very important aspect when choosing the micropiles. The geotechnical investigation, structural design and construction of the foundation supported with micropiles was successfully completed. A load test was also performed without geotechnical or structural failure. It was established that the Granodiorite Rock, geology of site and a vast area in the eastern part of Puerto Rico, is capable of developing relatively high grout-to-ground bond capacities.

PROJECT DESCRIPTION

The proposed project consists in the design and construction of a foundation system to support a telecommunication self-supported tower, with a height of about 200-feet as measured from ground surface.

The design and construction shall be done to suffice these tower reaction loads. The geotechnical investigation, foundation structural design and construction of the selected foundation system shall be provided. A value engineering analysis shall be provided to justify the foundation system selected.

SITE GEOLOGY AND SUBSOIL CONDITIONS

Basically, subsoil conditions detected consists of a two-layered soils stratigraphy. These are; residual soil, underlain by weathered granodiorite rock.

Very large and numerous boulders, as large as ten (10) feet in diameter or even more, are very common in this geologic scenario. These boulders are extremely hard to drill or excavate.

The groundwater table (GWT) at the site was not encountered during the subsoil exploration.

SUMMARY OF SUBSOIL CONDITIONS

Depth	Nspt Values	Soil/Rock Type
0-4 ft.	22-23 bpf	Medium Dense Sand
4-33 ft.	SPT Sampling Refusal	Highly to Moderately Weathered Granodiorite. Very Dense Sand or Soft Rock.
33+ ft.	Auger Refusal	Moderately to Slightly Weathered Granodiorite. Soft to Medium Hard Rock.

MICROPILE RECOMMENDATIONS AND DESIGN

A micropile is a small-diameter (typically less than 300 mm), drilled and grouted replacement pile that is typically reinforced. A micropile is constructed by drilling a borehole, placing reinforcement, and grouting the hole.

The geotechnical bond length tension and compression allowable axial load may be computed as follows:

$$P_{(G\text{-}allowable)} = (\alpha_{bond} * \pi * D_b * L_b)/FS \qquad (1)$$

Where:

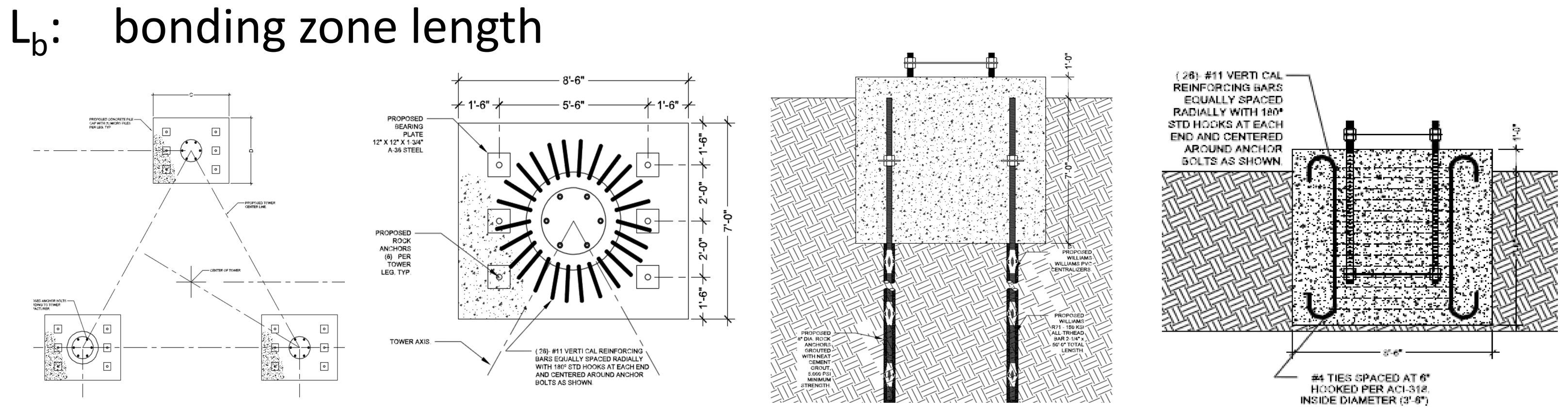
α_{bond}: grout to ground nominal bond strength

FS: factor of safety

D_b: diameter of the drilled hole

L_b: bonding zone length

Depth	(αbond nominal strength)
Bottom of Pile Cap	25 psi
20-30 ft.	40 psi
30+ ft.	75 psi



DESIGN VALUE ENGINEERING

In order to minimize the project cost, the very difficult access of the project shall be considered greatly. The main concern was how to get concrete to the site. Also, other materials such long steel rebar was a concern as well. Three foundation alternatives were considered. These are a mat foundation, three drilled shafts (one per tower leg), and micropiles with pile caps.

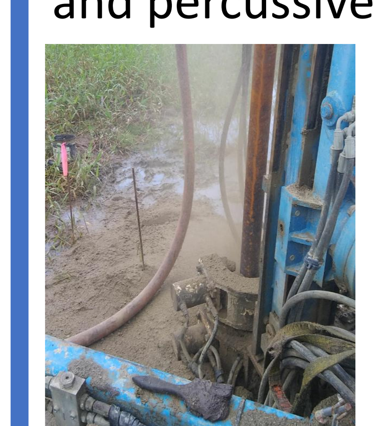
Foundation Type	Foundation Cost	Cost Reduction
Mat Foundation	$200,000.00	32.5%
Drilled Shafts	$185,000.00	27.0%

MICROPILES CONSTRUCTION

The most important aspect of this project was the construction of the micropiles. These will most of the controlling axial tension and compression loads of the proposed tower.

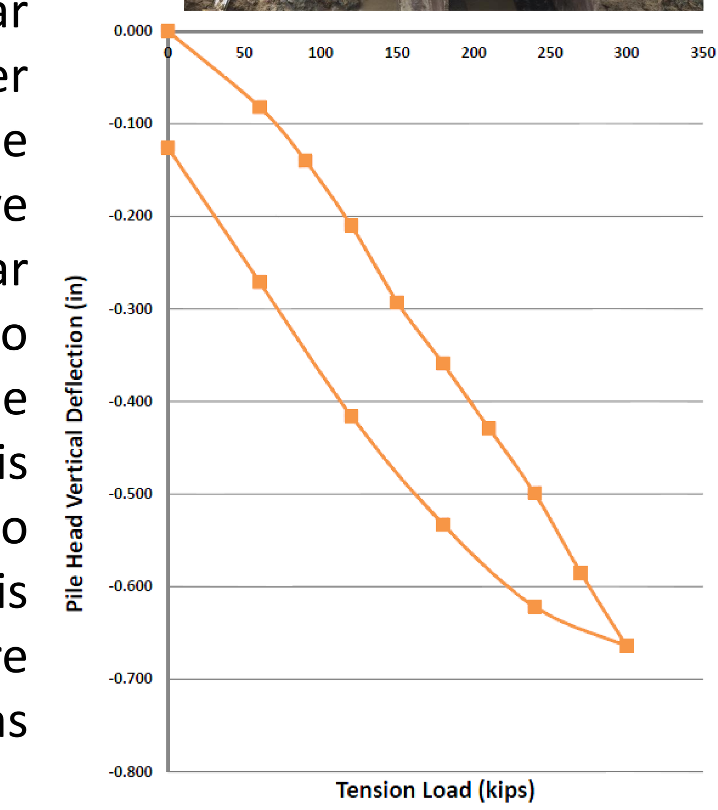
The construction of a micropiles in this project was a relatively simple process. The subsoil conditions allow for open hole drilling without the need of hole stabilization. No casing or slurries were required to maintain the hole open.

Percussion rotary drilling was used to drill though the Granodiorite Rock. The rotary-percussion drill is a type of rock drill that uses both rotary and percussive action in order to chip away rock and produce a hole.




MICROPILES LOAD TESTING

One proof test on a non-sacrificial micropile was tested to 100% of the design ultimate load of 300 kips. In general, the results of the load test showed an almost linear behavior. Failure of piles under tension test would be characterized with excessive deflections and a non-linear relationship of load to deflection, such was not the behavior observed for this test. Hence, no grout to ground bond failure is observed, nor structural failure of the reinforcing bar was observed.



PILE CAPS CONSTRUCTION

Once all micropiles construction have been completed and load test was performed, the construction of the pile caps was initiated.


CONCLUSION

It was shown that the use of the micropiles alternative resulted in a reduction of project cost. The estimated cost for the mat foundation and drilled shafts alternatives was $200,000.00 and $185, 000.00, respectively. The estimated cost of the micropiles alternative was $135,000.00. This represents a cost reduction of 32.5 percent and 27.0 percent for the mat foundation and drilled shafts, respectively.

The results of load test, performed on a non-sacrificial production micropile, showed that the micropiles can safely support the high magnitude 300 kips design ultimate load for each micropile. In addition, the load test showed that the weathered Granodiorite Rock, present at the project site and in a vast area in eastern part of Puerto Rico, is capable of developing relatively high values of grout to ground bond capacity. This last is of utmost importance, provided that general tendency of designers is to use lower values knowing a safe design will result. This "tendency" results in cost increases that are transferred to owner.