Micropiles Performance Based Design:

Evaluation of Current Design Methods Applied to Puerto Rico Soils

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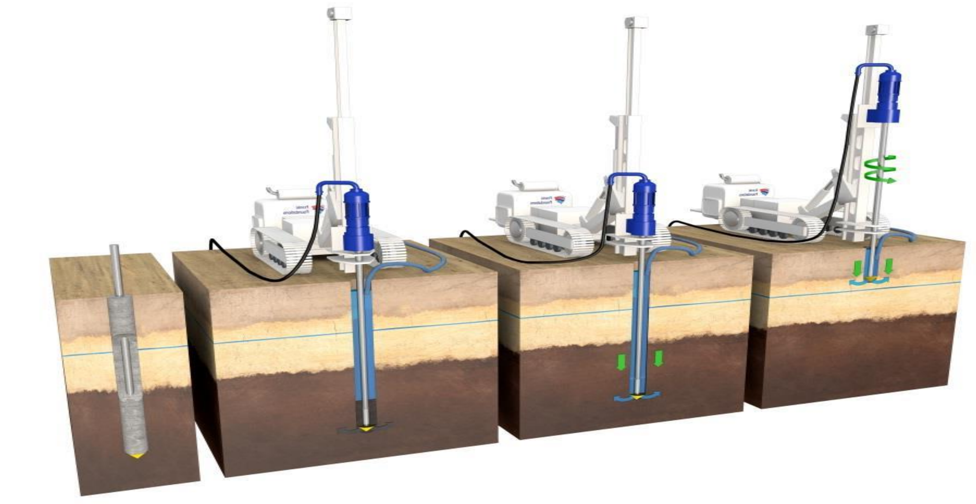


ABSTRACT

Micropiles have been used mainly as foundation support elements to resist static and seismic loads. The use of micropiles have been increased not only in locations with poor soil conditions, but also in congested areas and those requiring a less obtrusive presence than other installation methods may provide. This investigation reviewed results from tension tests performed on different soil scenarios and compared results of ultimate capacity with tension results. Comparison between actual capacity versus design values showed micropiles underestimation on micropiles installed in rock, opposed to an overestimation when installed in cohesive soils. Economic impact of overestimation has been approximated to 12% increment, based on one of the cases studied on this investigation. On the overestimation on rock anchors, further investigation is needed to determine the economic impact. This initial step into defining soil to grout bonding of micropiles for Puerto Rico soils sets place for more detailed investigations, targeted to provide better design values, hence reducing cost impacts on the construction phase of this elements. c

BACKGROUND

The maximum axial loads applied at the top of a micropile must be resisted by grout to ground bond over a specific length of the micropile. This is defined as the *geotechnical capacity* and is defined as:

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

Where:

- α_{bond}: grout to ground ultimate bond strength
- FS: factor of safety applied to the ultimate bond strength (typically from 1.5 to 2)
- D_b: diameter of the drill hole
- L_b: bonding length

A critical part of the design process is the determination of this bonding length. This is the most sensitive part of the design, since the grout to ground bond values are dependent of the type of soil and the density/consistency of the soil. The purpose of this project is to optimize the procedures established by the Federal Highway Administration for micropiles designed on Puerto Rico soils. This project is limited to study micropiles tensile axial capacities and does not intends to cover laterally loaded elements. The scope is limited in general to rocks, non-cohesive residual and cohesive residual soils. The main outcome expected is to identify if the parameters provided in the design manual by FHWA are suitable for the three types of soils under study. The project does not intend to set a standard for analysis, but to demonstrate that the use of the available parameters should be done properly and that there is a need to prepare a local database for the grout to ground bond values (α_{bond}) for the soils in Puerto Rico.

METHODOLOGY

The method for analysis targeted the use of stress vs. deformation curves generated from tensile tests performed in different types of soils. Aiming to perform a reverse engineering analysis to determine the αbond values used on these designs and cross reference those values published by FHWA in Table 1. Geotechnical capacity models were calibrated, by solving the soil to grout bond values based on the tension capacity results obtained from the tests using Equation (1). The interpretations of the results was followed by a Performance Based Design of the micropiles, in other words, the results from the tests will be evaluated with grout to ground values that approximate to the field test results.

Soil / Rock Description	Grout-to-Ground Bond Ultimate Strengths kPa (psi)			
	Type A	Type B	Type C	Type D
Silt & Clay (some sand) (soft, medium plastic)	35-70 (5-10)	35-95 (5-14)	50-120 (5-17.5)	50-145 (5-21)
Silt & Clay (some sand) (stiff, dense to very dense)	50-120 (5-17.5)	70-190 (10-27.5)	95-190 (14-27.5)	95-190 (14-27.5)
Sand (some silt) (fine, loose-medium dense)	70-145 (10-21)	70-190 (10-27.5)	95-190 (14-27.5)	95- 240 (14-35)
Sand (some silt, gravel) (fine-coarse, med.-very dense)	95-215 (14-31)	120-360 (17.5-52)	145-360 (21-52)	145-385 (21-56)
Gravel (some sand) (medium-very dense)	95-265 (14-38.5)	120-360 (17.5-52)	145-360 (21-52)	145-385 (21-56)
Limestone (fresh-moderate fracturing, little to no weathering)	1,035-2,070 (150-300)	N/A	N/A	N/A
Sandstone (fresh-moderate fracturing, little to no weathering)	520-1,725 (75.5-250)	N/A	N/A	N/A
Granite and Basalt (fresh-moderate fracturing, little to no weathering)	1,380-4,200 (200-609)	N/A	N/A	N/A

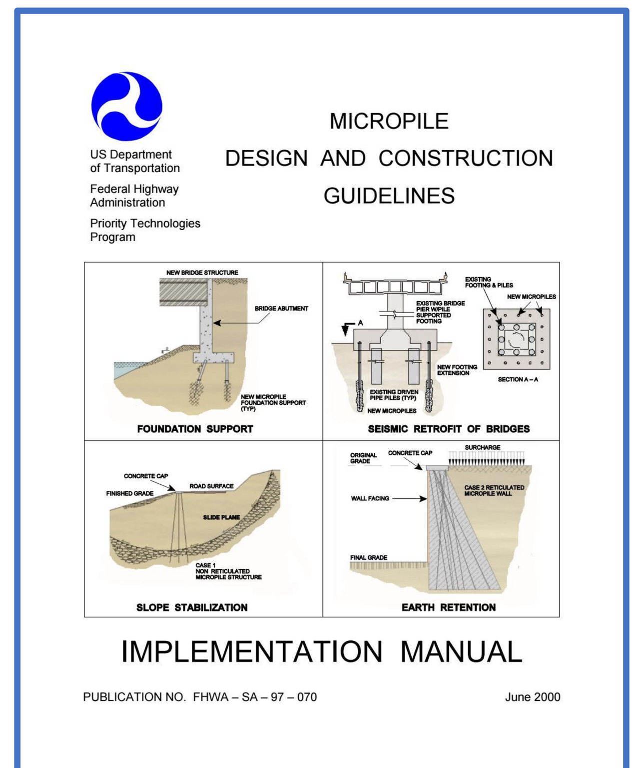
Table Notes:

Type A: Gravity grout only (All Cases on this Study)

Type B: Pressure grouted through the casing during casing withdrawal

Type C: Primary grout placed under gravity head, then one phase of secondary "global" pressure grouting

Type D: Primary grout placed under gravity head, then one or more phases of secondary "global" pressure grouting.



US Department of Transportation

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MICROPILE

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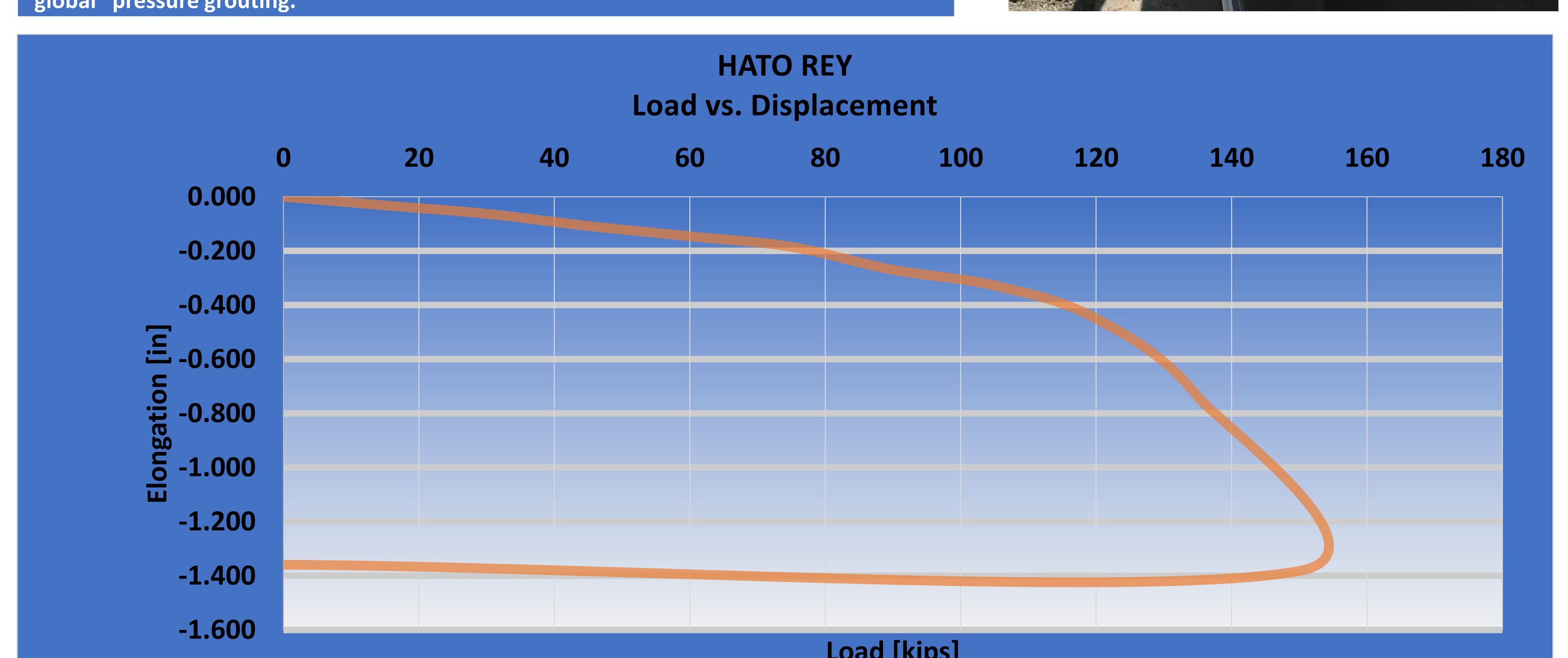

RESULTS

The grout to ground bond values in rock were underestimated. Values corresponding to gravel were used for rock. Both geotechnical and structural engineers without a solid background working with rocks, might tend to assign general properties to rock. Designers are likely to use lower values knowing a safe design will result. The underestimation of the ground to grout values resulted in longer micropiles. A test to failure would be required to quantify the actual a bond value for these materials. This could be part of further investigation.

The α_{bond} values on residual cohesive soils were overestimated for silts and clays as demonstrated on the Hato Rey Site. For this specific case, the overestimation resulted in the addition of 10% the original length of 55 feet, an additional load test, and the down time needed for the additional materials to arrive. This cost was directly transferred to client.

The only site where an a-bond could be determined based on the testing was on the Hato Rey Site. The reverse engineering analysis suggests an a-bond of 9 psi, a value in between the low and average range suggested in Table 1. On the Hato Rey case this had an impact in the project foundation part in the order of 12%, in dollar amount it represented an additional cost of $12,000USD, plus downtime costs. This project consisted of six production micropiles, if projecting this to a bigger size project the impact could had been sizeable.

The definition of geotechnical parameters to structural design is a delicate task. Lack of an appropriate subsoil model could lead to failing results due to overestimation, such as the case of the Hato Rey Site. Additional work is needed in the Hato Rey site. The fact that the ultimate capacity was tested, a deeper soil boring with continuous sampling is recommended.