Modeling the Axial Load-Displacement Behavior of a ACIP Pile in Very Dense Sand

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Abstract: In order to predict the axial load-displacement behavior of an ACIP pile, a two parameter non-dimensional hyperbolic relationship was investigated to represent the non-linear load-displacement behavior of the pile. Parameters used in the hyperbolic model were calculated from a full scale load test performed in Lufkin, Texas. The pile was loaded to over 350% of the design load during the load test. The ACIP pile with eight reaction piles did not reach the failure load. Hence the ultimate load was estimated using hyperbolic relationship and compared to the results from a 3D finite element model of the full scale pile load test.

1. Introduction:

Full scale compression load test on an instrumented ACIP Pile was performed at U.S. 7 near Lufkin, Texas. The ACIP Pile, which was 30 in. (760 mm) in diameter and 33 feet long, was constructed to support a bridge across East Cochino Bayou. The Texas Cone Penetrometer value is 50 blows for 4 in. in this site.

The axial load- displacement relationship was nonlinear and pile was tested up to 320 tons load. This limited the displacement to which the pile was tested and required an extension to load-displacement relationship to determine the ultimate bearing capacity. Chin et al. (1970, 1978) had used hyperbolic relationship to estimate ultimate capacity of piles, when load tests did not reach failure load and to investigate defects in driven piles. Kulhawy et al. (2004) have modeled the load-displacement relationship using linear and nonlinear segments. Vipulanandan et al. (2005) have used the non-dimensional hyperbolic relationship to predict the behavior of ACIP piles in soils. The entire system of pile material, soil and soil pile interaction are nonlinear and hence initial load displacement relationship will be nonlinear as observed in different studies.

2. Objectives:

To develop and verify models to predict the load-displacement relationship for a ACIP pile in very dense sand.

3. Analysis and Discussion:

Based on the inspection of the load displacement (ρ) relationships for the ACIP piles, the following conditions must be satisfied in developing a mathematical relationship.

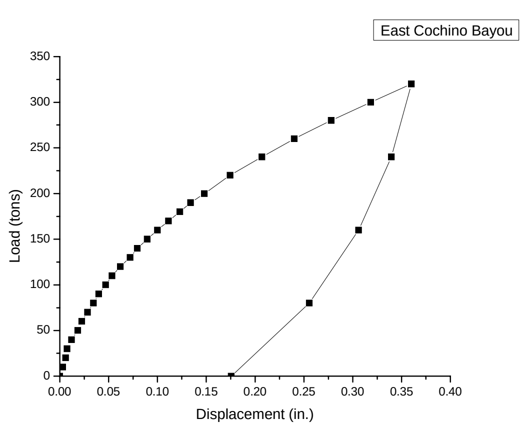

Fig 1. (Full scale load test of a ACIP pile near Lufkin, Texas (mixed soil profile))

$$\text{When } \rho \geq 0 \Rightarrow \frac{dQ}{d\rho} > 0$$

$$\frac{d^2Q}{d\rho^2} < 0$$

$$\text{When } \rho \to \infty \quad \frac{dQ}{d\rho} = 0$$

$$Q \to Q_{ult}$$

One mathematical relationship that will satisfy these conditions is the hyperbolic equation which can be represented as follows:

$$Q = \frac{\rho}{A + B\rho} \tag{1}$$

Where Q is the load, ρ is the displacement and A and B are equation constants. These constants can be calculated from the pile load test data. The parameter A is the reciprocal of initial tangent (Equation (1)) .When the displacement becomes large the pile capacity reaches its theoretical maximum (Qult) and it will be related to the parameter B as follows:

$$Q_{ult} = \frac{1}{B} \tag{2}$$

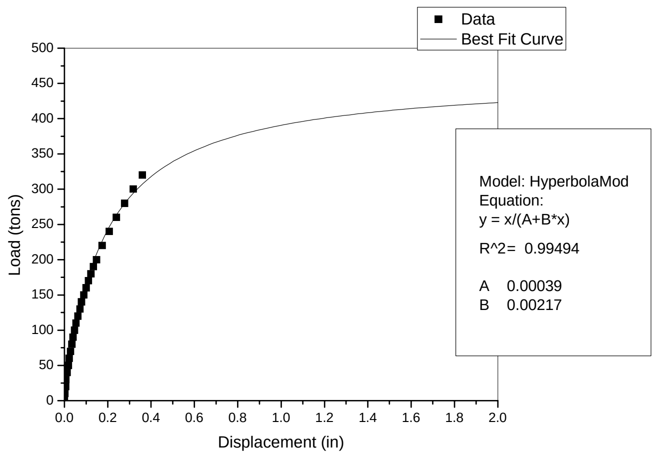

Fig 2. Hyperbolic Best Fit Curve.

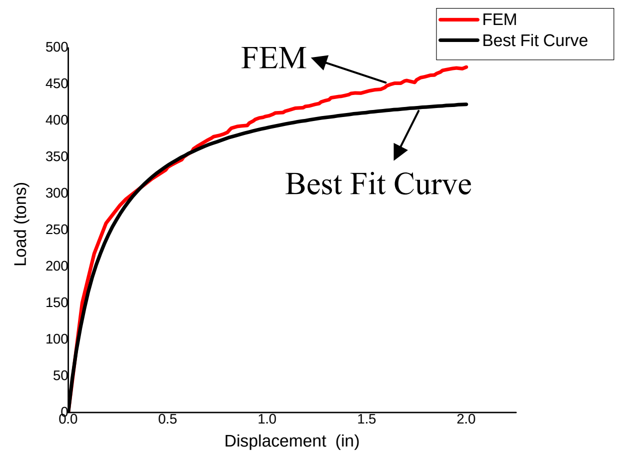

Fig 3. Best Fit Curve and FEM comparison.

Table 1. Comparison of Predicted and Measured Pile Capacities

Deflection δ=0.36 in.			Deflection δ/d=5%	
$Q^{measured}$ / δ=0.36 in.	$Q^{Hyp.}$/ δ=0.36 in.	Q^{FEM}/ δ=0.36 in.	$Q^{Hyp.}$ / δ/d=5%	Q^{FEM} / δ/d=5%
320	307	309	412	441
$Q^{Hyp.}$ / Q^{m} (δ=0.36in.)	Q^{FEM} / Q^{m} (δ=0.36in.)	$Q^{Hyp.}$ / Q^{FEM} (δ=0.36in.)	$Q^{Hyp.}$ / Q^{FEM} (δ/d=5%)	
0.96	0.97	0.99	0.93	

4. Conclusions:

Based on limited analysis, hyperbolic relationship and FEM model can be used to represent the load-displacement relationship of ACIP pile up to measured capacity. FEM model predicted higher capacity compare to the hyperbolic model at 5% (δ/d) displacement.

5. Acknowledgement:

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6. References:

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