POINT OF FIXITY OF LATERALLY LOADED PILES ON LAYERED SOILS

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Piles are critical structural elements that often face lateral loads from various sources, including moving vehicles on bridges, wind, waves, slope movement, and seismic activities. These lateral loads can cause substantial bending moments and lateral deflections in piles, which can compromise the structural integrity of the foundation. The point of fixity is a widely used concept in the design of laterally loaded piles, providing the necessary rigidity to withstand these forces and minimize deflections. While several analytical methods have been developed to determine the point of fixity in single-layered soils, their effectiveness and applicability in multilayered soils remain less certain.

This study investigates the validity of two commonly used analytical methods, Broms method and Kocsis method for determining the point of fixity in multilayered soils. The depth of fixity was estimated using average soil properties and compared against results obtained from more advanced approaches, including finite element modelling and p-y curve analysis, which consider distinct properties of individual soil layers. A comprehensive parametric study was also conducted to examine the influence of various factors, such as soil type, soil layer thickness, pile diameter, magnitude of lateral and axial loads, and pile embedment length, on the point of fixity.

The comparison revealed significant differences between the analytical methods, particularly in the context of predominantly cohesive soils. The Broms and Kocsis methods estimated the depth of fixity to be between 1.0 and 2.0 times the pile diameter below the ground surface, while the p-y curve and FEA methods yielded slightly more conservative values, ranging from 1.0 to 1.5 times the pile diameter. In predominantly cohesionless soils, the estimated fixity depths were more consistent across all methods, varying between 1.0 and 1.5 times the pile diameter below the ground surface. These findings highlight potential limitations in the applicability of traditional analytical methods to multilayered soils and underscore the importance of refining these approaches for more accurate and reliable design.

The parametric study further revealed that for long (flexible) piles, the depth of fixity is generally not significantly affected by factors such as surrounding soil type, layer thickness, axial load, and pile length. However, pile diameter and lateral load were found to have a substantial impact on the depth of fixity, with the effects varying depending on the analytical method employed and the soil's cohesive or cohesionless nature. Interestingly, the study also found that, even in single-layered soils, the Broms and Kocsis methods could yield results that significantly deviate from those obtained via p-y curve analysis. This discrepancy underscores the necessity for further detailed studies, including experimental work with instrumented pile tests, to enhance the accuracy and reliability of these methods.

Overall, the study suggests that the point of fixity in predominantly cohesive soils ranges from 0.5 to 2.5 times the pile diameter below the ground surface, whereas in predominantly cohesionless soils, it ranges from 0.5 to 2.0 times the pile diameter.

Keywords: Broms method, Kocsis method, Maximum bending moment, Multilayered soils, p-y analysis

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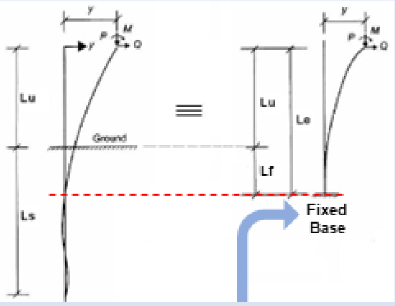
1. Background



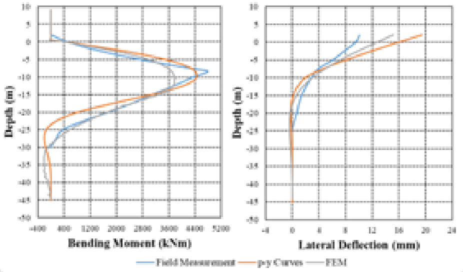
Location of the Point of Fixity

Method	Cohesive Soil	Cohesionless Soil
Broms Method	$1.5D_p + \frac{P}{9C_uD_p}$	$0.82\sqrt{\frac{P}{\gamma D_p\left(\frac{1+\sin\phi}{1-\sin\phi}\right)}}$
Kocsis Method	$0.5\sqrt[4]{\frac{E_pI_p}{k_sD_p}}$	$0.8\sqrt[5]{\frac{E_pI_p}{n_s}}$

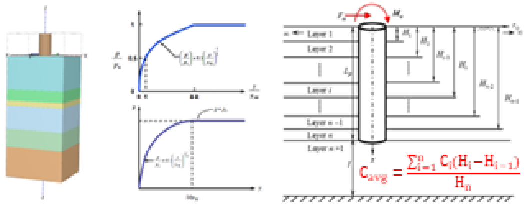
Depth of Fixity (Lf) from Analytical Methods

2. Methodology

2.1. Model Validation



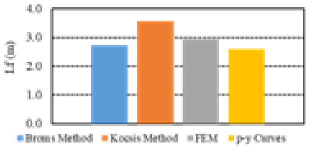
2.2. Estimation and Comparison of Depth of Fixity



$$C_{avg} = \frac{\sum_{i=1}^{n} C_i(H_i - H_{i-1})}{H_n}$$

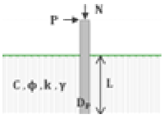
FEM p-y Analysis Analytical Methods

Comparison



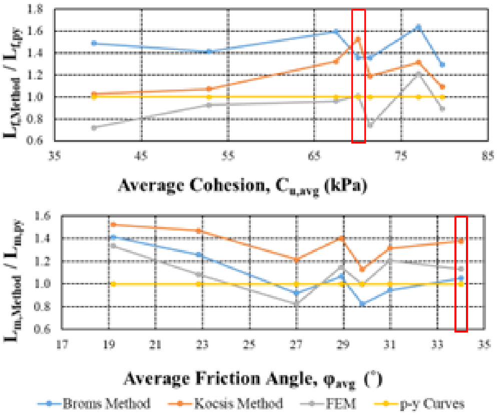
2.3. Parametric Study

Vary selected parameters while others remain unchanged

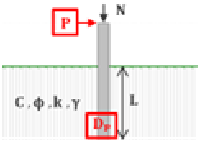


3. Results

3.1. Validity of Analytical Methods



3.2. Effect of Parameters



Significant Effect

Negligible Effect

Conclusion

- Considered analytical methods for multilayered soils have limitations
- Only lateral load and pile diameter significantly affect the point of fixity
- Point of fixity ranges: $0.5D_p$ - $2.5D_p$ depth below ground surface in cohesive soils, and $0.5D_p$ - $2.0D_p$ depth in cohesionless soils