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# Evaluating of 14H-Piles' Load Capacity in Cohesionless Soils for Edward's Project Using β-Method and Finite Element Method

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***Abstract: This paper presents a comprehensive study on evaluating the load capacity of 14H-piles in cohesionless soils for Edward's infrastructure project[1]. The project, overseen by the Federal Highway Administration (FHWA) and the Colorado Department of Transportation (CDOT), focuses on bridge replacements in Edwards, Colorado, with an emphasis on foundation improvements using driven pile foundations[2]. The research utilizes Finite Element Analysis (FEA) and the β-method to assess the total bearing capacity of 14H-piles in sandy soil conditions[3]. Field exploration, including Standard Penetration Tests (SPT), is conducted to determine soil parameters, followed by calibration of soil strength parameters. The study involves modelling the piles using the Soil-Structure Interaction 3-D program (SSI3D) and comparing the total bearing capacity obtained from FEA with nominal capacities calculated by the β-method. Additionally, the paper discusses load resistance and factor design, as well as the importance of static load testing for validation[4]. The results highlight the efficacy of FEA in predicting pile behaviour and provide valuable insights for foundation design in similar geological settings.***

***Keywords: 14H-piles, cohesionless soils, Finite Element Analysis (FEA), β-method, foundation design, static load testing***

## I. INTRODUCTION

The infrastructure development initiative led by the FHWA aims to improve interstate highways by replacing bridges, with a focus on Edward's Colorado[5]. The project involves replacing two bridges over the Eagle River and an inactive Union Pacific Railroad. CDOT recommends driven pile foundations for bridge abutments, necessitating evaluation of the total bearing capacity of 14H-piles in sandy soil conditions. Field exploration and soil parameter calibration are crucial steps in this evaluation process[6,7]. The paper provides an overview of the project background, emphasizing the need for foundation improvements and the significance of accurate load capacity assessment.

## II. METHODOLOGICAL DETAILS

Static load tests are described as the most accurate method for determining the actual load capacity of driven piles. These tests are essential during both the construction and design stages to present the load-displacement curve for piles installed in the field[8]. The methodology emphasizes the importance of careful planning and implementation of the static load testing (SLT) program. It highlights the need for using sensitive equipment like linear variable displacement transducers (LVDTs) and dial gauges to measure load and movement at the pile head accurately. This test focuses on the pile's ability to resist axial compression loads, which are common in actual conditions[9]. The procedure involves loading the top of the pile at a continuous rate and recording the movement at the pile head, along with the load-movement curve. Telltales, solid rods protected by tubes, are used to measure movement along the pile and evaluate the load transfer along the pile shaft[10,11]. The setup for compressional tests includes hydraulic jacks against a weighted platform, with a detailed description of the calibration and arrangement necessary for accurate measurement of pile head movements.

The primary objective in compression tests is obtaining a load-movement curve[12,13]. The methodology outlines equations for computing the elastic deformation of a pile, considering factors like test load, pile length, cross-sectional area, and the elastic modulus of the pile material. Instrumented static load tests help determine the values of shaft and toe resistances. The methodology describes how load transfer evaluation along the pile shaft can be determined using telltale rods or strain gauges[14,15]. The use of strain gauges, in addition to telltales, is recommended for obtaining accurate results.

The methodology details the types of strain gauges used for steel and concrete piles and the importance of ensuring these gauges remain dry to avoid failure due to corrosion[16,17]. A comprehensive analysis of the results would include a detailed comparison of the bearing capacities calculated by the β-method and FEM, discussing the significance of the findings in the context of soil properties and pile design[18,19]. It would explore the impact of soil parameters on pile performance, the interpretation of side shear and load-displacement curves, and the implications for pile foundation design in sandy soils[20,21].

## III. RESULTS

The study utilized more than fifty thousand equations to analyze the soil-structure interaction of a 14/102H-Pile under axial load. The extensive analysis, facilitated by SSI3D software, divided the pile and each soil layer into significant elements, resulting in a large stiffness matrix size.

The modeling of the 14H pile was executed down to 40 feet below the ground surface, with precise dimensions for the pile established for accurate simulation. Side Shear and Tip Resistance: The results highlight the side shear and tip resistance capacities for the piles tested. For instance, one segment of the results mentions a side resistance of 222 kips and a tip resistance of 70 kips. Load-Displacement Curves: Figures within the results section illustrate the load-displacement behavior of the piles, providing a clear visualization of the pile performance under varying loads. These curves are essential for understanding the pile's capacity and deformation characteristics under load. The study compares the bearing capacities calculated via two methods: the finite element method (FEM) and the β-method. The total bearing capacity was found to be 232 kips for B-3 using the FEM, while the β-method estimated it at 235.49 kips, demonstrating close agreement between the two approaches. The study emphasizes the reliability of FEM for foundation design, advocating for its use due to the conservative and accurate results it produces. FEM's detailed division into at least 40 layers for calculating side friction capacity is highlighted as a strength over the β-method, which divides the layer into 8 layers. The FEM is recommended for its conservative and practical approach to foundation design in the geotechnical engineering industry. The detailed analysis and the ability to divide the pile and soil into numerous elements for a comprehensive assessment make it a preferred method. These results contribute to a better understanding of the load-bearing capacities of 14H-piles in sandy soils, providing valuable insights for the design and construction of pile foundations in similar geotechnical conditions.

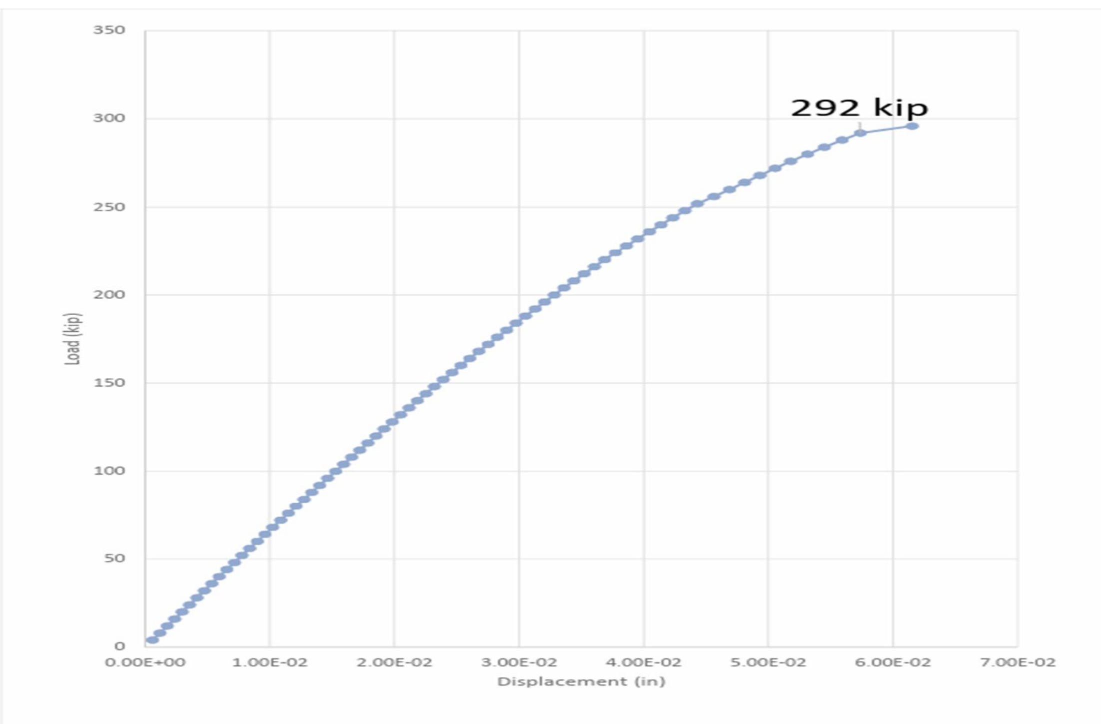


Figure 1: Load-Displacement Curve for H-Pile14/102 for B-9. The tip resistance = 70 kip

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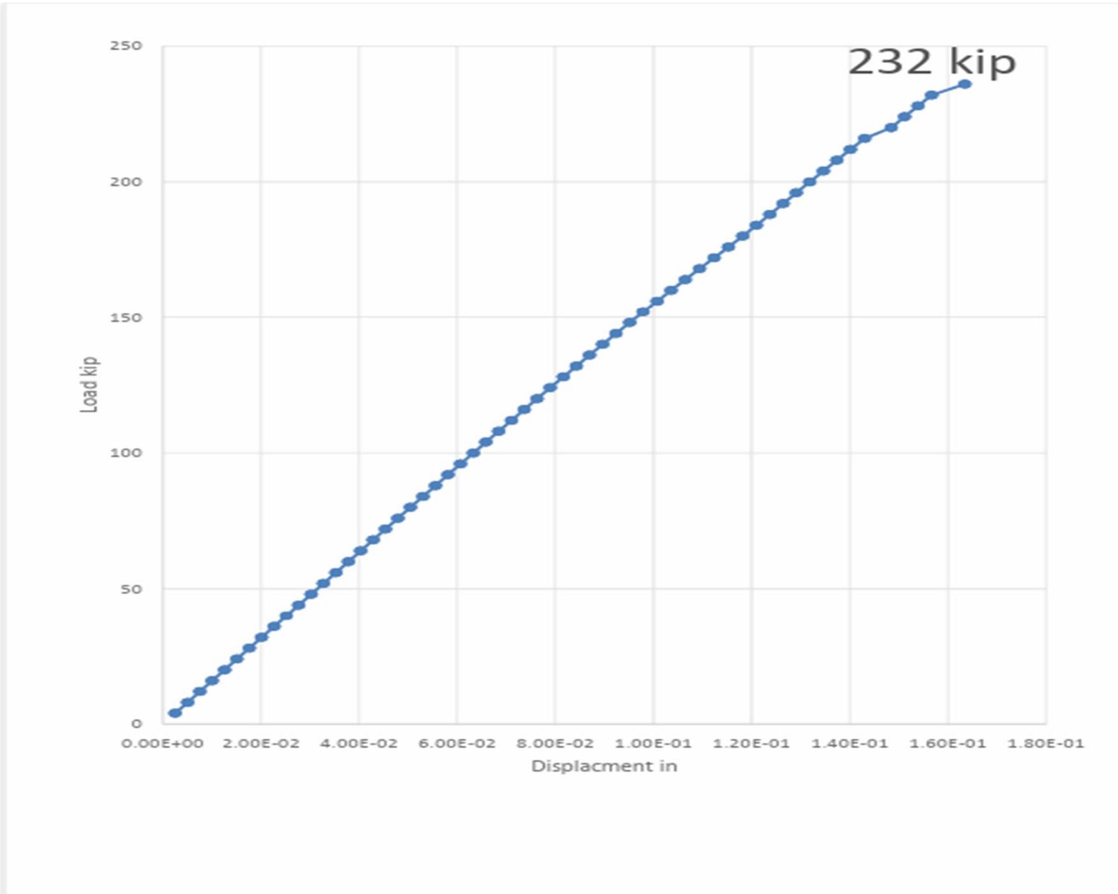


Figure 2: Load-Displacement Curve for H-Pile14/102 for B-3.

## IV. CONCLUSION

The Colorado Department of Transportation (CDOT) plans to replace two bridges in Edwards city, which initiated with site exploration using Standard Penetration Tests (SPT) to investigate soil conditions at various locations in Edwards, Co. All logging activities indicated that the soil composition was predominantly sandy, with underlying shale bedrock. Soil parameters calibrated from various equations revealed internal friction angles ranging between 30 to 45 degrees and unit weights between 90 to 120 lb./ft^3. It was noted that sandy soils lacked cohesion shear strength, whereas the shale bedrock exhibited a cohesion of approximately 33 psi. The study focused on evaluating the bearing capacity of 14H-piles, deemed the largest in the geotechnical industry according to Dr. Chang. The Finite Element Method (FEM) was applied due to its precision in analyzing such large piles. The FEM divided each pile into over 100 elements, each with six degrees of freedom, utilizing the SSI3D program for Soil-Structure Interaction in 3D. The analysis duration for each pile was approximately five hours. The side bearing capacities calculated via FEM for the southern and northern portions were 146 kips and 118 kips, respectively. In contrast, the β-method yielded side bearing capacities of 158 kips and 164 kips for the same portions, demonstrating a close correlation between the two methodologies. The study also reviewed load sources based on AASHTO Bridge Codes, categorizing them into dead loads and live loads. It emphasized the importance of utilizing factors to ensure structural resistance to these loads without failure and applying reduction factors to ascertain compliance with the LRFD AASHTO Code for Bridges. The intended evaluation of bearing capacity through static load testing was not realized due to delays in the instrumentation plan. Nonetheless, the study underscores the importance of such tests, especially for large-scale projects like Edward's project. The conclusion reiterates the efficacy of the Finite Element Method for foundation design within the geotechnical engineering realm, advocating for its application due to the conservative and practical results it delivers. While the study successfully bridges theoretical and practical aspects of pile load capacity evaluation, it suggests that future studies should incorporate static load tests to further validate the findings and enhance the design and construction of pile foundations in similar geological settings.

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