

INTISARI

Kegagalan fondasi pascakonstruksi pada tanah kohesif jenuh air sering kali dipicu oleh gangguan tanah (*soil disturbance*) yang ekstrem selama proses instalasi, yang secara kritis merusak asumsi desain awal. Penelitian ini mengkaji kegagalan penurunan kritis pada fondasi bored pile eksisting (diameter 0,30 m, panjang 13 m) yang menopang struktur *Heat Exchanger* (HE). Pengujian *Static Load Test* (SLT) di lapangan menunjukkan bahwa fondasi mengalami penurunan berlebih melampaui batas izin 25,4 mm hanya pada 20% pembebanan rencana akibat dewatering yang tidak optimal dan terbentuknya smear zone selama konstruksi. Penelitian ini bertujuan untuk mengkuantifikasi degradasi parameter tanah pascakonstruksi melalui *back-analysis* numerik, mengevaluasi mekanisme keruntuhan sistem *existing floating pile*, serta menyusun strategi perbaikan fondasi yang optimal. Metode Elemen Hingga 3 Dimensi (3D FEM) diaplikasikan untuk melakukan *back-analysis* dengan mengalibrasi kurva hubungan beban-penurunan numerik terhadap data aktual SLT lapangan. Zona gangguan instalasi dimodelkan secara eksplisit dalam radius 1,5D menggunakan model Mohr-Coulomb yang direduksi secara konservatif. Pendekatan-pendekatan analitis diintegrasikan untuk menentukan kedalaman tiang baru yang aman. Konsep "*Dis-Connecting Pile*" diusulkan dalam desain perbaikan, di mana tiang eksisting diputus dari *pilecap* baru dan difungsikan murni sebagai perkuatan tanah (*ground improvement*). *Back-analysis* 3D FEM berhasil meniru perilaku SLT aktual, mengungkap bahwa kuat geser dan kekakuan tanah di sekitar tiang telah tereduksi secara ekstrem hingga menyisakan 25% dari kekuatan awalnya. Akibatnya, kapasitas izin *existing bored pile* merosot menjadi 17,45 kN (hanya memenuhi 1/5 dari kekuatan rencana). Sebagai langkah perbaikan, direkomendasikan penambahan 16 tiang spun pile baru tipe *end-bearing* dengan kedalaman 25 m hingga mencapai lapisan tanah keras/batuan dasar dengan faktor keamanan (*SF*) 2,5. Validasi numerik pada desain perbaikan melalui dua kondisi analisis menunjukkan bahwa *spun pile* baru berhasil mereduksi penurunan vertikal menjadi hanya 9,63 mm hingga 12,10 mm, jauh di bawah batas kritis 25,4 mm. Pemanfaatan *existing bored pile* sebagai *ground improvement* terbukti efektif mengurangi transfer gaya dan momen lentur pada *pilecap* baru. Studi ini menegaskan bahwa *back-analysis* berbasis 3D FEM merupakan alat diagnosis yang kuat untuk menjembatani kesenjangan antara parameter desain ideal dan realitas lapangan pada tanah lempung jenuh yang sensitif. Selain itu, skema perbaikan fondasi *dis-connecting pile* menawarkan solusi yang andal, aman secara struktural, dan efisien untuk fondasi industri sensitif yang mengalami cacat pelaksanaan konstruksi dini.

Kata kunci: Kegagalan *bored pile*, *Static Load Test*, Gangguan tanah, *Smear zone*, *Back-analysis*, Metode Elemen Hingga 3D, Perbaikan fondasi.

ABSTRACT

Post-construction foundation failures in saturated cohesive soils often stem from severe soil disturbance during installation, which critically compromises design assumptions. This study investigates a critical settlement failure of an existing bored pile foundation (diameter 0.30 m, length 13 m) supporting a Heat Exchanger (HE) structure. Field Static Load Tests (SLT) revealed that the foundation experienced excessive settlement exceeding the 25.4 mm allowable threshold at only 20% of the design load, primarily due to suboptimal dewatering and installation-induced smear zones. This research aims to quantify the post-construction calibration of soil properties through numerical back-analysis, evaluate the failure mechanisms of the floating pile system, and develop an optimized foundation remediation strategy. A three-dimensional Finite Element Method (3D FEM) was applied to execute a back-analysis by calibrating the numerical load-settlement curve against the actual SLT field data. The installation-disturbed zone was explicitly modeled within a 1.5D radius using a heavily reduced Mohr-Coulomb model. Analytical methods were integrated to calculate the required depth for a resilient end-bearing pile system. A "Dis-Connecting Pile" concept was introduced for the remediation design, where the failed existing piles were decoupled from the new pile cap and repurposed exclusively as ground improvement elements. The 3D FEM back-analysis successfully simulated the actual SLT behavior, revealing that the surrounding soil shear strength and stiffness had reduced severely to 25% of their intact laboratory values. Consequently, the existing bored pile capacity plummeted to 17.45 kN, meeting only one-fifth of its designated design capacity. To remediate the foundation, a new system consisting of 16 end-bearing spun piles driven to a depth of 25 m into the hard bedrock layer was designed with a safety factor (SF) of 2.5. Numerical validation of the remediated system across two scenarios (with and without considering the existing piles) demonstrated that the new spun piles successfully restricted vertical settlements to a safe range of 9.63 mm to 12.10 mm, which is well below the strict 25.4 mm critical threshold. Repurposing the existing bored piles as ground improvement effectively minimized force transfers and bending moments within the new pile cap. This study highlights that 3D FEM-based back-analysis is a powerful diagnostic tool to bridge the gap between idealized design parameters and post-construction field realities in sensitive saturated clays. Furthermore, the disconnected pile remediation scheme offers a highly reliable, structurally safe, and resource-efficient solution for sensitive industrial foundations suffering from early-stage construction defects.

Keywords: Bored pile failure, Static Load Test, Soil disturbance, Smear zone, Back-analysis, 3D Finite Element Method, Foundation remediation.