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Framework for Consideration of Tool Selection in Bore Pile Work in Uncertain Field Conditions: Literature Study

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The selection of bore pile drilling equipment is a technical decision influenced by multiple interrelated factors. In construction practice, subsurface conditions cannot be fully determined during the planning stage, while operational constraints and considerations of time, cost, and risk further shape the decision-making process. This paper presents a literature-based review aimed at developing a conceptual framework for selecting bore pile drilling equipment, with emphasis on subsurface uncertainty and its implications for construction execution. The study adopts a literature review approach by examining relevant scientific publications, standards, and regulations from the past ten years. The findings indicate that equipment selection should not be viewed as a single or absolute decision, but rather as a multidimensional and context-dependent evaluation process. The proposed framework is intended to support practitioners and researchers in understanding drilling equipment selection as part of risk management in bore pile foundation works.
Keywords: Bore Pile, Equipment Selection, Subsurface Uncertainty, Construction Execution, Project Risk

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1. Introduction

Bore pile foundation work is widely used in construction projects, particularly in urban areas with limited space and stringent environmental requirements. In practice, drilling operations do not always proceed exactly as assumed during the planning stage. Even if soil investigations have been conducted according to standards, variations in soil conditions can still arise during construction, either in the form of changes in soil layers or groundwater conditions that affect the drilling process.

Various geotechnical standards and guidelines recognize that soil conditions are naturally variable, non-uniform, and cannot be absolutely guaranteed from the planning stage. SNI 8460:2017 states that soil parameters used in design are the result of interpretations of limited data, while Eurocode 7 (EN 1997-1) explicitly emphasizes that variations in soil conditions are normal and should be anticipated during work execution. Therefore, differences between planned and actual field conditions are an inherent characteristic of geotechnical work, not solely the result of planning errors.

In bore pile work, unexpected variations in soil conditions can directly impact drilling performance and the effectiveness of the equipment used. Several studies have shown that changes in soil conditions and groundwater levels during drilling can degrade the performance of certain methods or equipment, necessitating adjustments to field procedures (Chong & Ong, 2020; Phoon, 2022). Technical documents from the Federal Highway Administration also acknowledge the unpredictable subsurface conditions in drilled shaft operations and state that adjustments to drilling methods or equipment are acceptable technical responses as long as safety and quality requirements are met (FHWA, GEC No. 8 and GEC No. 10).

In addition to technical factors, drilling equipment selection in project practice is also influenced by operational considerations, time, cost, equipment availability, and the acceptable level of risk. Several studies in Indonesia have shown that the productivity and smoothness of bore pile operations are not determined by a single factor, but rather by a combination of various field conditions and resource management (Ardiyanti, 2023; Soetjipto et al., 2023). Therefore, the selection of bore pile drilling equipment must be understood as the result of multidimensional considerations under dynamic field conditions. This article aims to compile a literature review regarding the technical and operational consideration framework in the selection of bore pile drilling equipment by considering the potential for unexpected variations in soil conditions, in order to provide a more realistic and contextual picture of decision-making in construction practice.

2. Method

This research was conducted through literature review, focusing on scientific studies discussing bored pile foundation work, particularly regarding the selection of drilling equipment in the face of unpredictable field conditions. The research period covered scientific publications from the last five to ten years, with data sources drawn from international and national databases such as Google Scholar, ScienceDirect, and national journal portals. This approach was chosen because the research objective was not to evaluate equipment performance on a single project, but rather to develop a framework for understanding the technical and operational considerations that influence drilling equipment selection decisions in construction practice.

The research design employed a systematic literature review, with a targeted literature selection process using a combination of relevant keywords, such as bored pile work, variations in soil conditions, drilling equipment selection, and engineering decision-making. To ensure relevance, the Boolean operators AND and OR were used, ensuring that the literature obtained was not limited to one type of equipment or specific field conditions. The selected literature was limited to publications within the last ten years, openly accessible, and with a clear discussion context.

Data collection techniques included identifying, downloading, and recording literature that met the criteria. Relevant literature was then analyzed qualitatively by grouping findings based on considerations influencing drilling tool selection, including technical, operational, time, cost, and risk aspects. The analysis was conducted by reviewing similarities, differences, and trends in previous research findings.

The data analysis techniques used were descriptive and synthetic qualitative, with the aim of developing an adaptive and contextual framework for consideration in bore pile drilling tool selection. This framework is intended as an aid to understanding and assessing various decision options under dynamic field conditions, rather than as a rigid guide.

Relevant expert opinions supporting this research include, according to Li et al. (2022), the selection of bore pile drilling methods must consider the uncertainty of ground conditions and the flexibility of the tool to adapt to construction strategies. Wang and Chen (2021) emphasize the importance of integrating technical and operational considerations in drilling tool decision-making to minimize project risk. Meanwhile, according to Ahmad et al. (2023), adapting drilling methods to varying field conditions is a key factor in the success of modern bore pile projects, therefore, decision-making based on literature and practical experience is essential.

3. Results and Disccusion

Uncertainty of Soil Conditions in Bore Pile Work

In bore pile foundation work, soil conditions are often treated as a primary parameter in planning and selecting construction methods. However, various geotechnical literature and standards emphasize that soil conditions can never be known with certainty from the initial planning stage. Natural variations in soil layer composition, changes in mechanical characteristics, and the influence of groundwater can cause actual field conditions to differ from the initial assumptions used in the design (Phoon, 2022; Eurocode 7).

National and international standards explicitly recognize these limitations. SNI 8460:2017 states that soil parameters used in design are the result of interpretations of limited investigation data and therefore cannot fully represent the overall field conditions. Eurocode 7 also emphasizes that variations in soil conditions are an inherent characteristic of geotechnical work, so the construction process must anticipate the possibility of changing conditions during implementation. Therefore, differences between planned and actual conditions are not an anomaly, but rather part of the reality of foundation work.

This uncertainty in soil conditions has direct implications for the bore pile drilling process, particularly on the performance of the equipment used. Several studies have shown that changes in soil conditions or groundwater levels during drilling can reduce the effectiveness of certain tools, increase the risk of borehole instability, and slow the penetration process (Chong & Ong, 2020; FHWA, GEC No. 8). Other studies also indicate that variability in soil parameters affects the performance of pile foundations and their installation methods, particularly in unpredictable subsurface conditions (Zhang et al., 2016; Zhao et al., 2019). In this context, tool mismatch with field conditions is often reflected in decreased drilling performance, which can be technically observed through slowed penetration rates and increased operational disruptions during the drilling process (Qurnain et al., 2025).

Based on these studies, it is clear that technical considerations in selecting bore pile drilling tools cannot be separated from the uncertainty of the ground conditions encountered. Tool selection is not solely based on the assumption of ideal ground conditions, but rather on the tool's ability to maintain stable and adaptive performance when field conditions evolve beyond initial expectations. Therefore, the uncertainty of ground conditions should be viewed as a primary factor shaping the technical decision-making framework for bore pile work, rather than as a deviation from the standardized plan.

Operational Considerations in Bore Pile Work Implementation

In addition to technical aspects related to ground conditions, the selection of bore pile drilling equipment is also heavily influenced by operational considerations in the field. In construction practice, equipment that is technically capable of handling varying ground conditions may not be effectively applied if it is not compatible with the limitations of work space, mobility access, and the environmental conditions surrounding the project. Technical documents state that unpredictable subsurface conditions are a major source of risk in deep foundation work (FHWA, 2010; FHWA, 2018). Therefore, implementation aspects in the field are a critical factor that must be considered alongside the technical capabilities of the equipment.

Several studies have shown that limited working space in urban areas is often a major constraint in drilling equipment selection. Equipment with large operational space requirements, complex support systems, or complicated mobilization can disrupt other project activities and the surrounding environment, reducing work efficiency (Chong & Ong, 2020; FHWA, GEC No. 10). The technical guidelines for deep foundations also emphasize that fieldwork limitations are often a major limiting factor in the application of certain drilling methods (FHWA, 2010; Tomlinson & Woodward, 2015). In these circumstances, equipment selection

decisions should consider not only penetration capability but also ease of equipment setup in the field and operational flexibility during the work.

Noise and vibration are also operational considerations, particularly for projects in densely populated areas or adjacent to existing buildings. Some literature and technical guidelines indicate that noise and vibration limitations can influence the type of equipment and drilling method selected, even though alternatives may be technically faster or more aggressive (Eurocode 7; Regulation of the Minister of Public Works and Housing No. 22/PRT/M/2018). Thus, the suitability of the equipment is not only assessed by its performance on the soil, but also by its impact on the work environment and the project's surroundings.

In the context of project practice in Indonesia, research shows that the smooth running of bore pile work is greatly influenced by the equipment's ability to adapt to dynamic operational conditions, including space constraints, coordination with other projects, and the readiness of field resources (Ardiyanti, 2023; Soetjipto et al., 2023). This demonstrates that operational considerations cannot be separated from technical considerations in drilling equipment selection. Decisions based solely on technical specifications without considering constructability have the potential to create implementation obstacles, work delays, or increase operational risks during construction.

Time, Cost, and Risk Considerations in Drilling Equipment Selection

In addition to technical considerations and field conditions, time, cost, and risk are important factors shaping the decision to select bore pile drilling equipment in project practice. In many cases, the equipment decision is not solely aimed at achieving the highest technical performance, but also at ensuring the work can be completed within acceptable time and cost limits. Therefore, equipment selection is often a compromise between technical capabilities and the associated managerial consequences.

In terms of execution time, unexpected variations in field conditions can directly impact the duration of drilling work. Several studies have shown that equipment mismatches with field conditions often lead to drilling process delays, operational disruptions, and the need for work method adjustments, leading to implementation delays (Chong & Ong, 2020; FHWA, GEC No. 8). In this context, time is influenced not only by equipment speed but also by the stability of the drilling process and the frequency of disruptions during the process.

Cost aspects are also inseparable from time and risk considerations. Equipment selection costs include not only rental or mobilization costs but also indirect costs arising from work delays, rework, or method adjustments in the field. Several studies in Indonesia have shown that equipment with a lower initial cost does not necessarily result in lower total costs if it causes implementation disruptions or reduced productivity during bore pile work (Ardiyanti, 2023; Soetjipto et al., 2023). This demonstrates that cost evaluations need to consider operational risks and potential changes in field conditions from the outset.

Project risk bridges technical, time, and cost considerations when selecting drilling equipment. Uncertain ground conditions and field limitations increase the risk of technical failure, delays, and cost overruns if the selected equipment lacks sufficient flexibility. Geotechnical literature emphasizes that decision-making under these conditions requires considering the equipment's ability to mitigate risk, rather than simply pursuing efficiency under ideal conditions (Phoon, 2022; Eurocode 7). Therefore, the selection of bore pile drilling equipment can be understood as a risk-management decision, where the balance between time, cost, and uncertainty is a key consideration in construction practice.

Synthesis of the Framework for Considerations in Bore Pile Drilling Equipment Selection

Based on the previous discussion, the selection of bore pile drilling equipment is a decision-making process involving various interrelated considerations. Uncertainty in soil conditions forms the initial technical

constraints, field conditions determine the feasibility of implementation, while considerations of time, cost, and risk play a role in assessing the consequences of the decision from a project management perspective.

This synthesis emphasizes that equipment selection cannot be understood as a single, absolute decision, but rather as the result of a multidimensional, contextual evaluation. The framework presented serves as a conceptual tool for understanding the interaction between technical and non-technical factors in the dynamic practice of bore pile construction.

Table 1. Considerations for the Selection of Bore Pile Drilling Equipment

Group Considerations	Key Focus	Implications for Decisions
Uncertainty of Soil Conditions	Unpredictable variations in soil and groundwater levels	Requires equipment that can perform stably and adapt to changing conditions
Field Operational Considerations	Limitations in space, access, the surrounding environment, and work coordination	Limits the feasibility of using certain equipment even if it is technically adequate.
Implementation Time	Potential delays due to drilling disruptions and method adjustments	Encourages the selection of equipment that can reduce the risk of recurrent failures
Project Cost	Direct and indirect costs due to implementation changes	Requires an evaluation of the total cost, not just the initial cost of the equipment
Project Risk	Technical and operational uncertainties during implementation	Directs decisions toward equipment that reduces overall risk

4. Conclusion

This study demonstrates that the selection of bore pile drilling equipment cannot be understood as a single, absolute decision. Uncertain soil conditions, limitations in field implementation, and the implications of time, cost, and risk create a complex and interrelated decision-making environment. Differences between planned and actual conditions are inherent in deep foundation work and must be rationally anticipated. The framework developed in this article positions equipment selection as part of the risk management process in bore pile work. This approach is expected to assist practitioners and researchers in assessing equipment selection decisions more adaptively, contextually, and in harmony with dynamic field conditions.

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