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Soft Soil Ground Improvement Technology Using The Top-Base Method

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ABSTRACT: Construction on soft soil foundations requires appropriate ground improvement solutions to ensure stability, safety, and economic efficiency. Among the currently available ground improvement technologies, the Top - Base method is considered an advanced solution with several notable advantages. This method employs funnel-shaped concrete blocks (Top-Blocks) in combination with granular materials to redistribute and reduce stresses transmitted to the soft soil, while simultaneously restraining lateral deformation and reducing foundation settlement. This paper presents an overview of the characteristics of soft ground and several methods for soft soil improvement. It also analyzes the working principle, structural configuration, construction method, and construction procedure of the Top - Base foundation. The results indicate that the Top - Base method can significantly enhance the bearing capacity of the ground, shorten construction time, and reduce construction costs, making it particularly suitable for shallow foundations constructed on soft soil.

KEYWORDS: Soft soil, Ground improvement, Top - Base method, Shallow foundation

I. INTRODUCTION

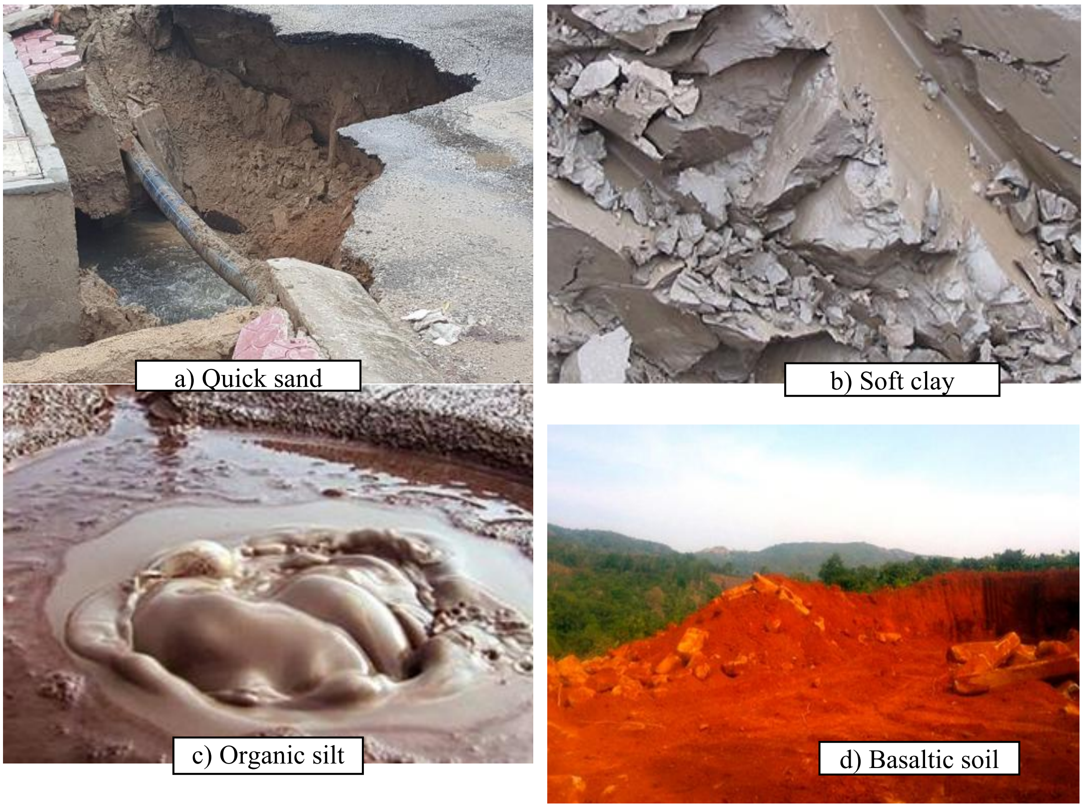
The soil foundation plays a pivotal role in all civil engineering structures, directly dictating both the quality and the operational lifespan of the project. The identification and classification of soft soil are generally approached from two perspectives: qualitative and quantitative.

Qualitative Perspective: Soft soil is defined as a soil type that inherently lacks the necessary bearing capacity to support the loads imposed by overlying structures, such as buildings, roadways, or embankments.

Quantitative Perspective: Soft soil is characterized as having poor bearing capacity and a high susceptibility to failure or excessive deformation under structural loads. This classification is determined by specific physical and mechanical property indices [1].

Based on physical properties, soil is classified as soft when key indices meet the following criteria: unit weight γ_w<= 1,7 T/m^3; void ratio e >= 1; moisture content W >=40%; and degree of saturation G >=0,8. Alternatively, based on mechanical properties, soft soil is identified by low bearing capacity, R = (0,5÷1) kG/cm^2; modulus of deformation E_0<= 50 kG/cm^2; compression coefficient
a >= 0,01 cm^2/kG; internal friction angle j <=10^{o}and cohesion (for cohesive soils) c <= 0,1 kG/cm^2[1, 2].

In Vietnam, the Red River and Mekong Delta basins—characterized by thick alluvial layers and concentrated soft clay deposits—are areas of significant urban and infrastructure development. This reality necessitates the implementation of advanced and appropriate ground improvement technologies [3]. Common types of soft soil, such as soft clay, quicksand, organic silt (sludge), and basaltic soil, as illustrated in Figure 1, are fundamentally composed of layers with organic origins resulting from plant decomposition, containing mixtures of clay and sand materials. Alternatively, they may consist of fine sand with loose grain structures that become significantly liquefied, transitioning into a flowing state known as quicksand. Basaltic structures are also prevalent, characterized by high porosity, low dry unit weight, high permeability, and a high susceptibility to collapse or excessive settlement [4-6].



SOME COMMON TYPES OF SOFT SOILS[4- 6]

For structures built on soft ground, the selection of an appropriate soil improvement method depends on the physico-mechanical properties of the soft soil layers and the specific structural characteristics. The primary objectives of these methods are to enhance the bearing capacity, minimize settlement, and ensure the normal operational conditions of the project. Researching soft soil improvement techniques is a complex task that requires extensive experience and deep expertise in geotechnics and foundation engineering [7]. In Vietnam, several widely adopted methods include sand cushions, dynamic compaction, pre-loading, sand drains, prefabricated vertical drains (PVD), reinforcement with bamboo and Melaleuca piles, vacuum consolidation, and deep soil mixing using lime or cement columns [4-8], which are summarized in the table below.

No.	Method	Content	Effects	Applications
1	**Sand Cushion Method**	Excavate and remove the soft soil layer, replacing it with compacted medium to coarse sand.	Increases the bearing capacity of the foundation, enhances structural stability, and reduces the depth of foundation burial, thereby saving foundation materials.	Soft soil layers with a thickness of < 3m. Not recommended for areas with high groundwater levels due to instability and high costs of dewatering.

No.	Method	Content	Effects	Applications
2	**Dynamic Compaction Method**	Compact the surface soil layer using vibrating rollers or heavy weights (10-15 tons).	Enhances the strength and bearing capacity of the soil while reducing its compressibility.	Soils with high porosity, loose sand, or uncompacted soils.
3	**Pre-loading Method**	Apply a surcharge (bricks, stones, gravel, etc.) equal to or greater than the design load.	Increases the bearing capacity, accelerates consolidation, and ensures settlement stability.	Water-saturated sandy silt, clayey silt, organic silt (sludge), and peat.
4	**Sand Drain Method**	Install sand piles (30-40 cm diameter) using vibrating casing technology to displace soil, followed by filling with sand and compacting.	Provides drainage, accelerates consolidation, and increases the strength of the sand-pile foundation (composite of sand piles and surrounding soil).	Soft soil foundations thicker than 3m; not used in extremely fluid/soft soils.
5	**Prefabricated Vertical Drain (PVD) Method**	Pore water in the soil permeates through the geotextile filter into the plastic core, which acts as a drainage path.	Accelerates consolidation rate, reduces porosity, increases unit weight, and enhances bearing capacity.	Large thickness of soft soil layers with low permeability.
6	**Reinforcement with Bamboo and Melaleuca Piles**	Install bamboo or Melaleuca piles (2.5 - 6m long) with a density of 20-25 piles/m².	Increases bearing capacity and reduces foundation settlement.	Continuously saturated soil foundations and structures with light loads. Not suitable for sandy soils.
7	**Deep Soil Mixing (Lime or Cement Columns)**	Inject lime or cement into the soil through boreholes at a predetermined ratio.	Reduces moisture content (5-8%), increases cohesion (1.5-3 times), and enhances bearing capacity.	Soft clays, plastic silty clays, and sludge.
8	**Vacuum Consolidation Method**	Use vacuum pump technology to extract water from the soil,	Increases consolidation speed and bearing capacity while reducing	Soft clay foundations (commonly used in China, Japan, and

No.	Method	Content	Effects	Applications
		forcing rapid consolidation.	compressibility.	Vietnam).

In general, researching soft soil improvement methods is a complex undertaking that demands extensive experience and profound expertise in the field of geotechnical engineering. Nevertheless, the application of innovative construction technologies is considered essential to drive the industry toward modernization, sustainability, and alignment with global trends. Specifically, construction execution consistently requires high adaptability to diverse field conditions, including weather variations and complex soil profiles, while simultaneously satisfying criteria for structural safety, aesthetic quality, cost-efficiency, and accelerated construction schedules. Among the emerging technologies for soft ground reinforcement today, the Top-Base foundation system has garnered significant attention from investors and practitioners alike, the detailed analysis of which will be presented in the following sections [9, 10].

2. TOP-BASE TECHNOLOGY FOR SOFT GROUND REINFORCEMENT

2.1. The Top-Base Foundation Method

"Top-Base" has established itself as an international technical term, formally known as the Top-Base Foundation Method. In recent years, this innovative foundation technology, originating in Japan and South Korea, has garnered significant interest for its ability to enhance soil bearing capacity and optimize foundation structures. Structures constructed on Top-Base foundations demonstrated remarkable resilience during catastrophic earthquakes, such as the 1987 Chiba and 1995 Kobe earthquakes, sustaining virtually no damage. Extensive theoretical and experimental studies have been conducted to evaluate the efficacy of this method, with findings published in prominent Japanese geotechnical journals and presented at international conferences on ground improvement.

Since the early 1990s, the technology has been extensively researched and applied in South Korea,
reduction in construction costs by up to 50%, thereby contributing to the overall economic efficiency of the

leading to numerous significant innovations. Notably, Korean advancements have streamlined the construction process, making Top-Base installation faster, simpler, and more environmentally friendly. By the 1990s, over 2,000 projects in South Korea had utilized Top-Base foundations; in 2007 alone, more than 8 million Top-Block concrete units were deployed, reinforcing approximately 2 million square meters of ground [10–16]. In Vietnam, the Top-Base method has been implemented in several key projects, including the Hon Dau Resort (Do Son, Hai Phong), the Cruise Terminal (Tuan Chau, Quang Ninh), Thang Long International School, the South Building (Ho Chi Minh City), and the Licogi Vocational College of Technology. However, this technological solution has yet to achieve widespread adoption in the local construction industry [2, 4, 5].

2.2.Characteristics of the Top-Base Foundation Method

The implementation of Top-Base technology for soft ground reinforcement has become a global trend in the construction industry, owing to its superior features compared to traditional methods. The fundamental principle of the Top-Base system is to provide a comprehensive ground improvement solution that enhances the bearing capacity of the soil, minimizes settlement, and accelerates the consolidation process.

Structurally, a Top-Base foundation is composed of numerous funnel-shaped (top-shaped) concrete blocks arranged closely together in a single horizontal plane (Figure 2). The interstitial voids between these blocks are subsequently filled and compacted with granular materials, such as crushed stone or lean concrete. This specialized configuration allows for a significant reduction in the consumption of structural materials, specifically steel and concrete, during the foundation construction phase.

Compared to conventional foundation techniques, the adoption of Top-Base technology can yield a
Additionally, as a non-piled foundation solution, the Top-Base method minimizes environmental

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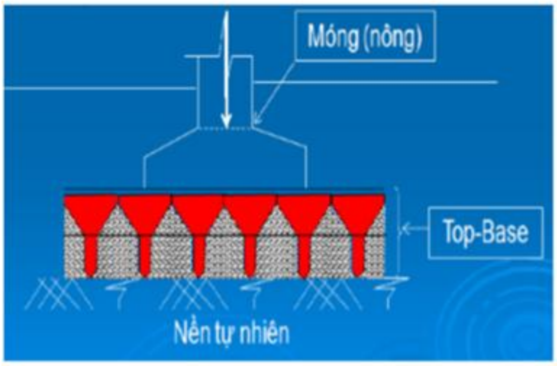
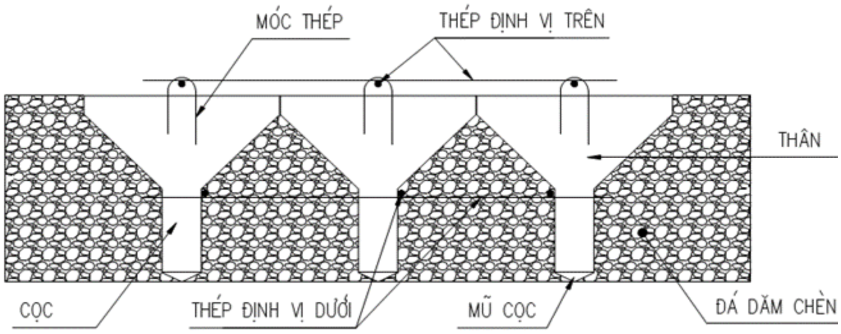
project. Furthermore, the interlocking structural mechanism of the foundation can enhance the ultimate bearing capacity by 50% to 200%. disturbances and eliminates adverse impacts on adjacent existing structures.



STRUCTURE OF THE TOP-BASE FOUNDATION [1]

2.3 Strucure of the Top- Base foundation
The individual components of the Top-Base foundation system are illustrated in Figure 3 below:



COMPONENTS OF THE TOP-BASE FOUNDATION

Top-Block: This is the term for the funnel-shaped concrete block, cast using high-quality concrete within a funnel-shaped plastic mold. The block is designed with a 45-degree tapered angle and is embedded within a compacted crushed stone bed. When a load is applied to the upper surface of the Top-Block, it is distributed uniformly across its peripheral area. Consequently, the load is gradually dissipated due to the 45-degree inclined working direction and the friction between the Top-Block and the surrounding crushed stone. This mechanism significantly reduces the initial load before it reaches the natural soil foundation.

Plastic Funnel: This is a funnel-shaped plastic mold, serving as a component member arranged in systematic rows at the designed locations. Once filled with concrete, these molds form the Top-Blocks.

Top-Base Layer: The interstitial spaces between the Top-Blocks are filled with crushed stone (size 1–2.5 cm) and thoroughly compacted. The Top-Blocks are then rigidly interconnected by steel reinforcements within a surface-locking concrete layer, creating a Top-Base course beneath the structural foundation, also known as a Top-Base foundation. Figure 4 below illustrates the actual construction process of a Top-Base foundation.

ACTUAL CONSTRUCTION IMAGES OF THE TOP-BASE FOUNDATION

3.CONSTRUCTION OF THE TOP-BASE FOUNDATION

There are two primary solutions for constructing this type of foundation: utilizing precast Top-Blocks manufactured at a factory or casting the blocks in-situ at the construction site. Fundamentally, these two technological approaches differ only in whether the precast Top-Blocks are arranged directly or the plastic molds are positioned first and then filled with concrete. Subsequently, crushed stone is filled and compacted into the interstitial spaces between the blocks. The complete technological process for Top-Base foundation construction consists of the following steps:

3.1. Earth Excavation

Soil is excavated to a specific design depth. If the excavation depth exceeds 1.0 m, appropriate measures for trench shoring and dewatering must be implemented to ensure the safety and stability of the excavation throughout the construction process.In cases where the bottom of the excavation is located above the groundwater table and the existing soil is loose, the base must be further compacted, and a geotextile layer should be laid before positioning the precast Top-Blocks. Figure 5 below illustrates the excavation process and the reinforcement of the trench walls using steel sheet piles to maintain stability during the Top-Base foundation construction.

EXCAVATION AND TRENCH SHORING USING LARSEN SHEET PILES

3.2.Installation of precast Top- Blocks or In- situ casting molds

Top-Blocks are cast from concrete into a shape resembling an upright spinning top. The Top-Base foundation is constructed by systematically installing these blocks. During installation, it is crucial to ensure that the elevations of the steel markers attached to the concrete funnels are uniform.

The pile-shaped base of each funnel is driven vertically and securely into the ground within the triangular grids provided by the positioning steel mesh. In cases where the existing ground is excessively hard, pre-drilling or chiseling may be required to properly embed the funnel bases.

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INSTALLATION OF PRECAST PLASTIC FUNNEL MOLDS

CONCRETE PLACEMENT USING PUMPS AT THE PLASTIC FUNNEL MOLD LOCATIONS

In-situ Concrete Casting for Top-Blocks

In cases where Top-Blocks are cast in-situ, the prefabricated plastic funnel molds must be installed at the precise design locations prior to concrete placement, following a similar procedure to the installation of precast blocks mentioned above. To ensure the concrete is thoroughly compacted within these plastic funnels, a vibrator may be used if the concrete mix has a low slump. Alternatively, manual rodding or shoveling can be applied if the pumped concrete has a high slump. This process is illustrated in the figure above.

3.3.Filling with crushed stone

Approximately 24 hours after concrete placement, the process of filling and compacting crushed stone is performed to eliminate the interstitial voids between the concrete Top-Blocks. This is a critical stage because the foundation structure fundamentally determines the quality and integrity of the Top-Base system. Therefore, this step must be executed in strict accordance with technical specifications, requiring the utmost care and precision. The compaction of the crushed stone is typically carried out using manual steel rods for small volumes, or mechanical internal vibrators to ensure thorough densification in cases involving larger surface areas or greater block depths.

FILLING AND COMPACTING CRUSHED STONE TO CREATE THE TOP-BASE STRUCTURE

3.4. Surface- locking and interconnecting Top- Blocks

The combination of steel reinforcement and concrete serves to rigidly lock the tops of the Top-Base foundation units, thereby enhancing their overall bearing capacity. Once the Top-Blocks have been installed and the crushed stone has been thoroughly compacted, all surfaces must be cleaned. Subsequently, a steel mesh is installed, and a concrete layer with a minimum thickness of 100 mm is cast to achieve the monolithic integration of the entire foundation structure.

In this stage, D10 mm steel bars are tied in two perpendicular directions with a spacing of approximately 500 mm. This reinforcement mesh is securely anchored to the steel hooks of the concrete funnels, creating a continuous structural network over the foundation base. Consequently, once the concrete has cured, it forms a robust and unified structural system, providing a high degree of stability and homogeneity to the foundation.

STEEL MESH INSTALLATION AND CONCRETE PLACEMENT TO FINALIZE THE TOP-BASE FOUNDATION STRUCTURE

4. CONCLUSION

This paper has synthesized and analyzed several widely applied soft ground reinforcement methods, clarifying the scope and application conditions for each technique. The Top-Base method is introduced as an advanced ground improvement solution that bypasses traditional piling while still ensuring effective load dissipation. The operational principle of the Top-Base foundation demonstrates a significant reduction in stress transmitted to the soft soil through an inclined load distribution mechanism and frictional resistance. Furthermore, the structural configuration and construction procedures of Top-Base foundations are relatively simple and flexible, making them suitable for diverse geological conditions and various construction site constraints.

The analytical results indicate that the Top-Base method markedly enhances the bearing capacity of the soil and effectively mitigates differential settlement for shallow foundation structures. Compared to traditional ground treatment solutions, Top-Base technology helps shorten construction schedules and substantially reduces overall construction costs. This method is particularly suitable for projects built on relatively thin layers of soft soil that require rapid progress and minimal impact on adjacent structures. In the future, further experimental research and detailed computational analysis are necessary to refine the design framework and expand the application of Top-Base technology within the Vietnamese construction industry.

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