Ground Improvement Technique

A Project Report Submitted
For the Partial Fulfilment of the Continuous Assessment of Bachelor of Technology in Civil Engineering Course of MEGHNAD SAHA INSTITUTE OF TECHNOLOGY under MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY for the Session 2019-2023

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2019-2023

Declaration

This Project Report titled **"Ground Improvement Technique"** is prepared and submitted for the partial fulfilment of the continuous assessment of Bachelor of Technology in Civil Engineering Course of MEGHNAD SAHA INSTITUTE OF TECHNOLOGY under MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY for the Session 2019-2023. It is declared that no part of said work has been presented or published elsewhere.

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RECOMMENDATION CERTIFICATE

It is hereby certified that this **Project Report** titled **"Ground Improvement Technique"** is prepared and submitted for the partial fulfilment of the continuous assessment of Bachelor of Technology in Civil Engineering Course of MEGHNAD SAHA INSTITUTE OF TECHNOLOGY under MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY for the Session 2019-2023 under my supervision and guidance.

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ACKNOWLEDGEMENT

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I would like to acknowledge that this project was completed entirely by me and not by someone else.

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CONTENTS

PRINCIPLE:

Stone Column is a vertical shaft form by back filling compacted and crushed stone gravel or sand or moisture of these granular or material to form granular pile or 1. They are used for all types of planned structures including building, foundations, damns, tanks, towers, embankment, etc.

Stone Column is a technique used in civil engineering to improve and stabilize soils Considered weak as soft clays or silts and loose sands, enabling the construction of highway Facilities, storage tanks, embankments, bridge abutments and so on. This technique uses columns
Filled with a well compacted coarse grained material, which are allocated all over in the in situ soil. Because material of the columns is stiffer, more permeable and has a higher shear strength then the natural soil, we end up with an improvement of the soil properties: increase of the bearing
capacity due to shear strength increase; reduce of total and differential settlements due to stiffness
improvement; decrease time for the settlements to occur and reduce of liquefaction potential of
cohesive soils due to increase of the soil mass permeability acting as a vertical drain.
In this research we are interested mainly in the potential of Stone Columns to reduce settlement. When it comes to constructions which the main problem is reducing the settlement,
This technique is a very common solution applied by Ground Engineering Companies for being Considered as a low cost alternative, effective and ease of installation. Once this technique is pretty .
Much common among industry, there are many studies to improve the design method in order to
make the calculation process simpler and to get more accurate results helping engineers to predict .
The behavior of the soil due to the insertion of stone columns realistically and driving to reliable Conclusions about the degree of improvement achieved

Basic Design Parameters

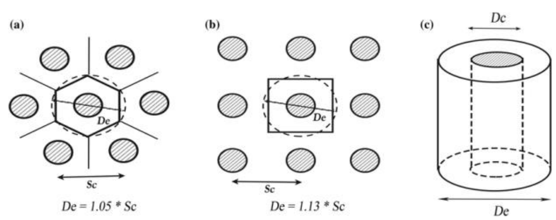
In stone column construction, usually 15 to 35 percent of the weak soil volume is replaced by stone. Design loads on stone columns typically vary from 20 to 50 tons. The presence of the column creates a composite material of lower overall compressibility and higher shear strength than the native soil alone. Confinement, and thus stiffness of the stone, is provided by the lateral stress within the weak soil. Upon application of vertical stress at the ground surface, the stone and weak soil move downward together resulting in an important concentration of stress within the stone column. The resulting stress concentration in the stone is primarily due to the column being stiffer than the soil.

Stone Column Diameter (d)

The column diameter is dictated by the desired level of improvement, the method of installation, the stone size and the strength of the in-situ soil. Reported column diameters range from 1.5 ft. (0.45 m) to 4.0 ft. (1.2 m). Besancon et al. (1984) developed a graphical correlation between the column diameter and the undrained shear strength of the soil using actual reported case applications. The lower portion of their proposed graphical band corresponds to stone columns constructed using less than 40-mm size material while the upper portion represents columns with materials up to 100-mm in size.

Pattern of Columns

attern of Columns Stone columns can be installed in a triangular arrangement or a square shaped arrangement. Stone columns are constructed usually in an equilateral triangular pattern although a square pattarn is sometimes used. The equilateral triangle pattern gives the most dense packing of stone columns in a given area. A typical layout of stone columns in an equilateral triangular pattern is shown in Fig



Spacing of Columns (s)

The design of stone columns should be site specific and no precise guidelines can be given on the maximum and the minimum column spacing. However, the column spacing may broadly range from 2m to 3m depending upon the site conditions, loading pattern, column factors, the installation technique, settlement tolerances, etc. For large projects, it is desirable to carry out field trials to determine the most optimum spacing of stone columns taking into consideration the required bearing capacity of the soil and permissible settlement of the foundation.

Equivalent Diameter (De)

For purposes of settlement and stability analyses, it is convenient to associate the tributary area of soil surrounding each stone column with the column as illustrated in Figs. 4. Although the tributary area forms a regular hexagon about the stone column, it can be closely approximated as an equivalent circle having the same total area. The equivalent circle has an effective diameter (De) which is given by following equation: De = 1.05 S …for an equilateral triangular pattern, and = 1.13 S …for a square pattern where, S = spacing of the stone columns.

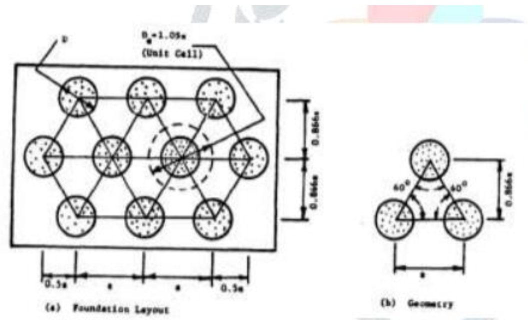


Fig 4 - Equilateral Triangular Pattern of Stone Columns

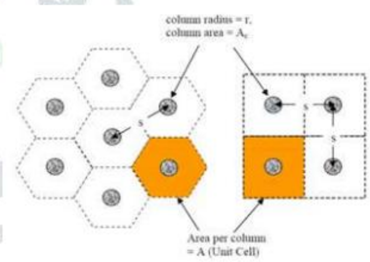


Fig 5- Unit Cell Idealization

The resulting equivalent cylinder of composite ground with diameter De , enclosing the tributory soil and one stone column is known as the unit cell, as shown in fig. 5

Replacement Ratio (as)

The composite ground representing an infinitely wide loaded area may be modeled as a unit cell comprising the stone column and the surrounding tributory soil. The volume of soil replaced by stone columns has an important effect upon the performance of the improved ground. To quantify the amount of soil replaced by the stone, the term, replacement ratio, as is used. Replacement ratio (as) is given by : as= As/ A = As / (As + Ag) where As = area of the stone column, Ag = area of ground surrounding the column, A= total area within the unit cell. The area replacement ratio may also be expressed as follows: as = 0.907 (D/S)2 where the constant 0.907 is a function of the pattern used which, in this case, is the commonly employed equilateral triangular pattern

Stress Concentration Factor (n)

Stress concentration occurs on the stone column because it is considerably stiffer than the surrounding soil. From equilibrium considerations, the stress in the stiffer stone columns should be greater than the stress in the surrounding soil. The stress concentration factor (n) due to externally applied load σ, is defined as the ratio of average stress in the stone column, σs, the stress, σg, in the soil within the unit cell. n = (σs / σg) The value of n generally lies between 2.5 and 5 at the ground surface. The stress concentration factor, n, increases with time of consolidation and decreases along the length of the stone column. Higher n value at ground surface may result if load is applied to the composite ground through a rigid foundation as compared to the flexible foundation. The stress concentration factor, n, may be predicted using elastic theory as a function of the modular ratio of the stone and the clay assuming equal vertical displacements. However, as the modular ratio can vary within wide limits, it should be selected from the above given equation

Drawback:

Stone column should not be used in soils with undrained shear strengths less than 14 kN/m2 because of low radial support afforded to stone columns

Stone Columns Technique

This chapter is to give a brief introduction of how the Stone Columns technique is used to improve the soil: how the columns are built, what its advantages and disadvantages and the concepts used in the various methods for calculating Settlement Improvement Factor.

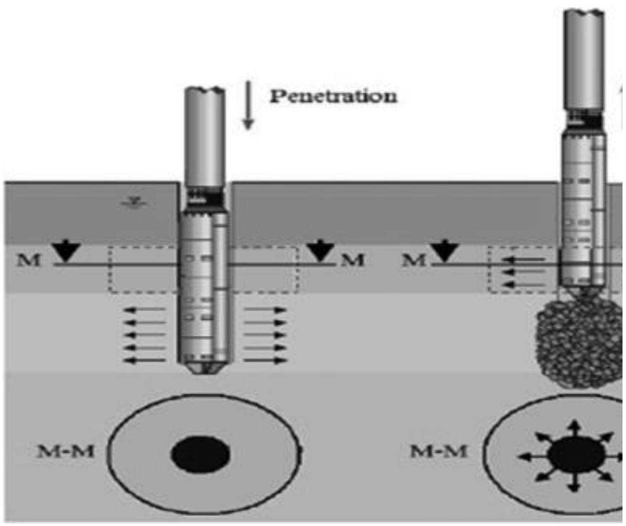
2.1 Construction and feasibility

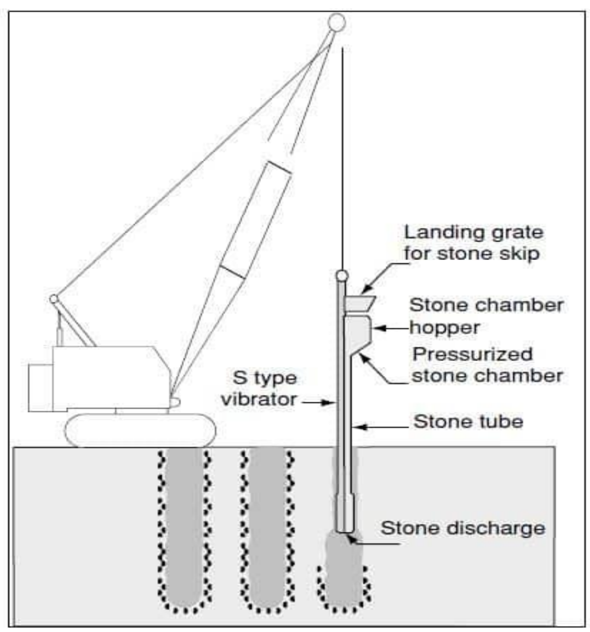
As mentioned before, Stone Columns construction involves the partial replacement of unsuitable weak soils from the more superficial layers with vertical columns filled with coarse and well compacted aggregates of various sizes, penetrating the weak strata to create structural elements to be based on a stiffer layer. The columns are considered not to affect significantly the properties of surrounding soil, acting mainly as inclusions with higher stiffness, shear strength and permeability than the natural soil (Castro & Sagaseta, 2008). As the column material is stiffer than the natural soil, the load applied on the surface is no longer equally distributed, but a major part is taken by the columns, relieving the load on the compressible soil and thus reducing the settlement of the soil.

Soil improvement can be achieved using Stone Columns with a gain of bearing capacity, reduction and acceleration of settlements and mitigating the potential of liquefaction, making possible to replace the deep foundations with shallow ones, thus facilitating design and reducing costs. The effectiveness of this technique may be compromised when the layer of soft soil grows too thick and amounts of organic materials get too high, leading to a situation where the excessive Compressibility and low strength of the natural soil results in too little lateral support for the Columns and extremely large vertical deflections of columns resulting a local bulging failure of the structure .

Construction procedure

Stone column construction begins at the bottom of the treatment depth and is worked up to the surface. With the help of its weight, vibration, and often water jets in its tip, the vibrator penetrates the ground using the wet top feed technique. The firm soils may also be predrilled through if poor penetration is experienced.

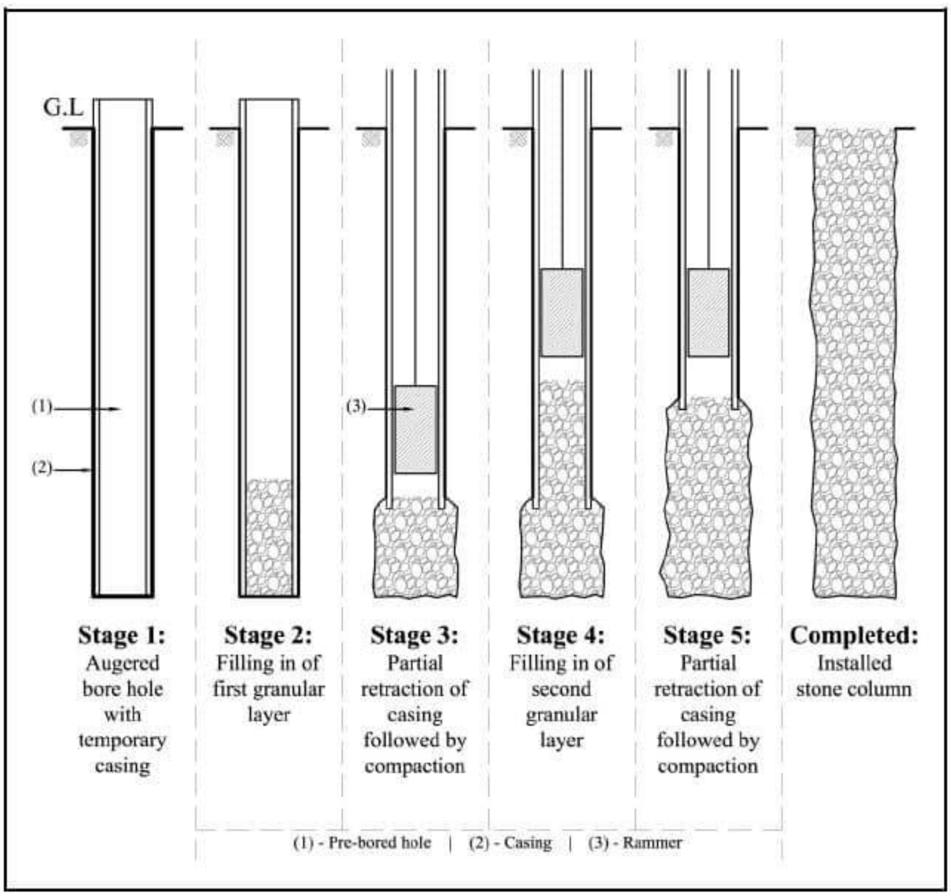




The stone is placed around the vibroflot by a front end loader at the surface of the ground, and it falls to the tip of the vibroflot to the tip, filling the void created when the vibroflot if lifted, and the vibrator is then raised a few feet. The stone is subsequently compacted and displaced in lifts of 2 to 3 feet (0.75 to .9 m) wheb the vibroflot is periodically raised and lowered as it is extracted.

Typically, the flushing water is sent to a settlement pond where it is permitted for the soil fines suspended in the water to settle. When using the dry bottom feed process, the vibroflot only needs its weight and vibrations to help it enter the earth. Predrilling may once more be performed if required or preferred . The subsequent steps are then similar, with the exception that the stone is sent through the tremie pipe to the tip of the vibroflot. It has been possible to treat at depths of up to 100 feet (30 meters).

In general, two mechanical techniques – Vibration and ramming-are used to install these columns. Rammed columns are placed by first generating a pre-bored hole which is afterwards filled with a ompacted material in many layers as opposed to vibrated columns which employ a vibratory probe to generate an opening for granular fill placement by either the displacement or the replacement method.



Installation of a pre-bored rammed stone column

The difficulty of the installation is hat distinguishes the two method. Vibrated columns are more expensive than rammed columns because they require more advanced equipment and experienced labor.

Applicable soil type:

The performance of soils is enhanced by stone columns in two ways:

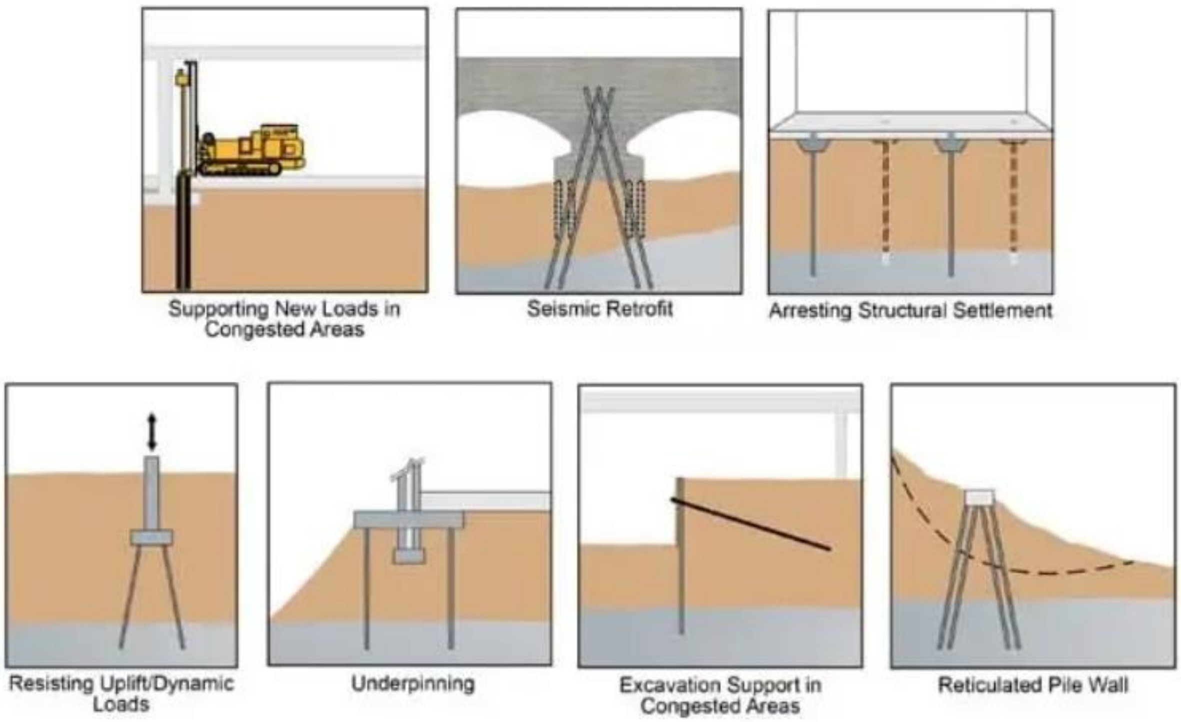
1. First, By densifying the surrounding granular soil, and second, by reinforcing the soil with a stiffer, higher shear strength column. Table 1 displays the anticipated improvement for various soil types . In most cases, it does not matter how deep the gound water is.

Soil Description	Densification	Reinforcement
Gravel and sand <10% silt, no clay	Excellent	Very good
Sand with between 10 and 20% silt and < 2% clay	Very good	Very good
Sand with >20% silt and nonplastic silt	Marginal(With large displacements)	Excellent
Clays	NA	Excellent

MICRO PILE:

PRINCIPLE:

The principle of micro piles technology is to directly form holes on the designed pile position, use the drilling rig to break and grind the rock stratum, use the air compressor



to exert pressure to bring out the drilling slag, form holes by the soil or rock mass structure, or use the mud to protect the wall.

DRAWBACK:

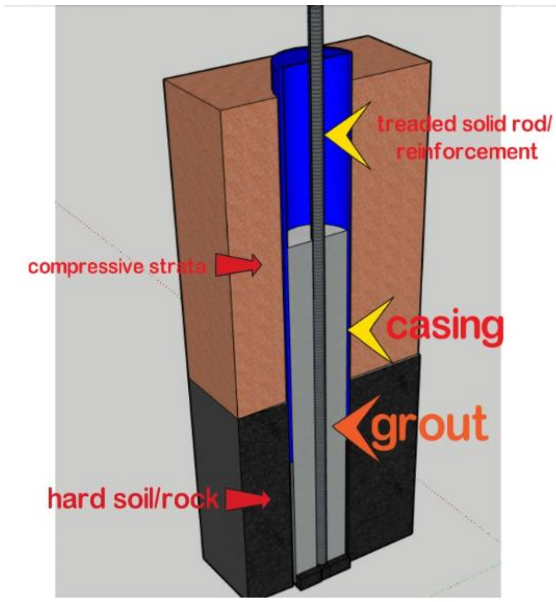
It takes longer to overwhelm them with no obstacles than they would be with a driven pile. This is an expensive resource. Water infiltration often causes problems

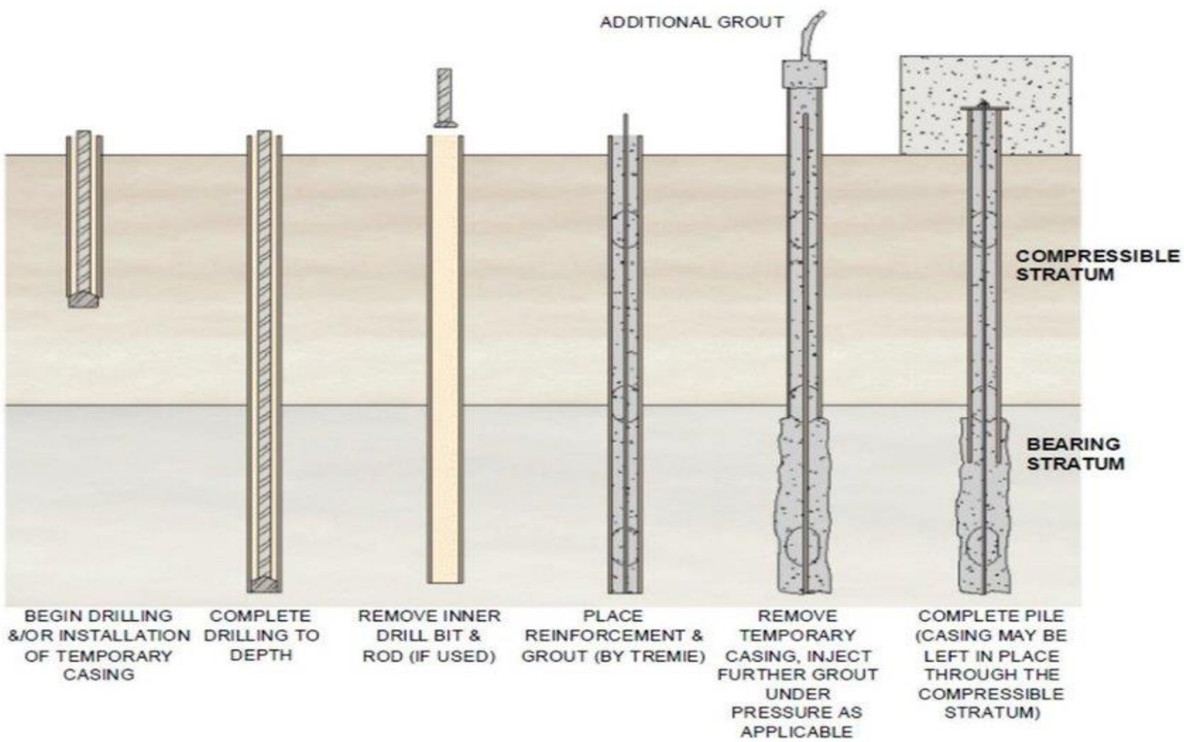
The disadvantage of micro piles is the **relatively high cost** as compared to other piling systems except for the case of shallow pile termination depth.

Micro piles are generally classified firstly according to design application and grouting method.

CONSTRUCTION PROCEDURE:

1. Positioning and drilling of the first drilling of the first section of the drill casing (recoverable steel casing as temporary support during the boring process).
2. While drilling, the drill casing – inside equipped wih a drilling head fixed on a rod is oscillated into the soil. (back and forth movement/ twisting in place).
3. As the drilling process progresses, soil is removed from the borehole by the excavating and additional sections of casing are joined(added) to protect the soil from collapsing into the borehole during drilling..
4. After reaching the design depth, clean-up of the borehole front, removal drilling tool, drilling fuid pumped out from the bore Formation of the pile: insertion and lowering of the reinforcement case, pouring of the concrete
5. During the continuous concreting process, the temporary casing elements are progressively withdrawn whereby the concrete forms the pile shaft.





Steps of micro pile construction

CONSTRUCTION OF MICRO PILE:

Drilling Techniques The drilling method is selected on the basis of causing minimal disturbance to the ground and nearby sensitive structures and able to achieve the required drilling performance. In all drilling methods, drilling fluid is used as a coolant for the drill bit and as a flushing medium to remove the drill cuttings. Water is the most common drilling fluid compared to other drilling fluid such as drill slurries, polymer, foam and bentonite. Another type of flushing medium is using compressed air, which is commonly used in Malaysia

Single tube advancement: By this method, the toe of the drill casing is fitted with an open crown or bit, and the casing is advanced into the ground by rotation of the drill head. Water flush is pumped continuously through the casing, which washes debris out and away from the crown.

Rotary duplex: With the rotary duplex technique, drill rod with a suitable drill bit is placed inside the drill casing. It is attached to the same rotary head as the casing, allowing simultaneous rotation and advancement of the combined drill and casing string.

Rotary percussive duplex: Rotary percussive duplex systems are a development of rotary duplex methods, whereby the drill rods and casings are simultaneously per cussed, rotated, and advanced. The percussion is provided by a top-drive rotary percussive drill head. This method requires a drill head of substantial rotary and percussive energy.

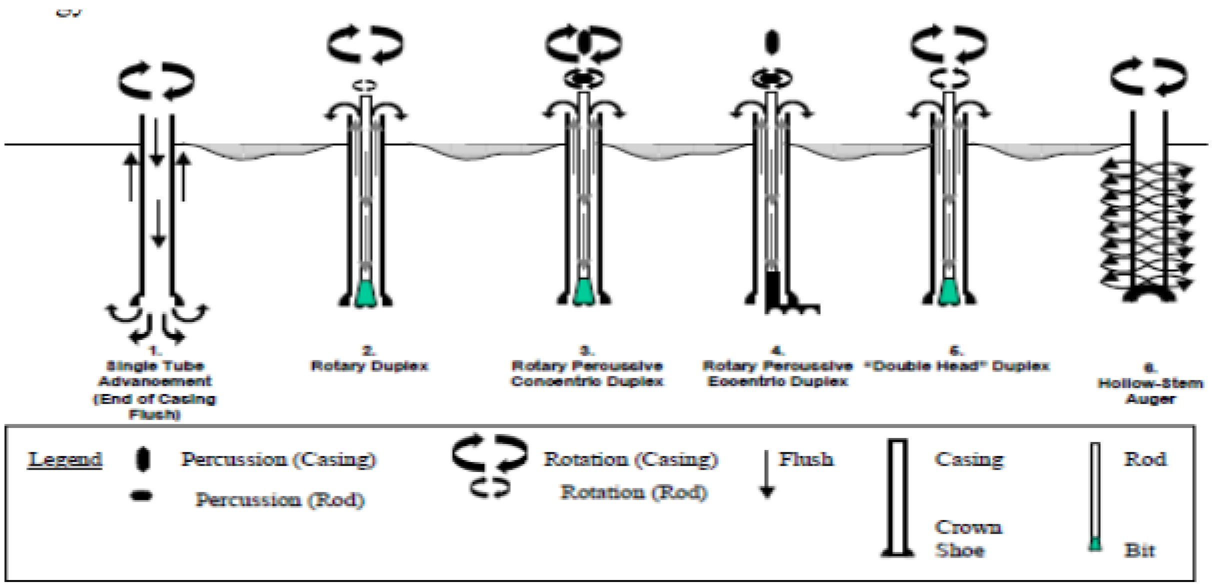


Fig VI.I Schematic representation of the six generic overburden drilling methods

Grouting

Micro pile grouting equipment consists at a minimum of a colloidal high speed, high shear mixer, holding tank with agitation, grout pump capable of reaching pressures of 300 psi, pressure gauges, recirculation lines, qa/qc equipment and log books. The colloidal mixer is a high-shear grout plant that is capable of rapidly mixing neat cement based grout in a few minutes, with a thorough wetting of the individual cement grains. A thorough wetting allows a low water-cement ratio grout to be pumped easily through the grout lines that run from the plant to the pile. Without a colloidal plant, clumps of cement will cling together, clogging injection lines, and ultimately yielding a lower strength grout, because significant amounts of the cement grains are not hydrated. Following a thorough mixing, the grout must be stored in an agitation tank with agitation blades that constantly stir the mixed grout, prolonging separation of the cement from the mix water. With proper admixtures, grout life may be extended easily to a working time of 6 hours, and in some cases, may be suspended indefinitely until the reaction

is re-initiated on demand. A Marsh Cone simplifies optimization of the grout mix design with respect to retarders and fluidifiers. A Marsh Cone time of 11 – 14 seconds is typically considered ideal for pumping into micro pile packer systems

TYPES OF SOIL/ CONDITION:

. The types of soil that most often require piling are those with high clay or silt content since these are fine-grained soils. They tend to collapse more easily, or else cause more uplift when they freeze.

Sandy soils are stronger but can still cause problems, while soils with high organic content can also be too weak to support traditional foundations. This is most likely to be on land previously used for agriculture or horticulture, but it can be found elsewhere.

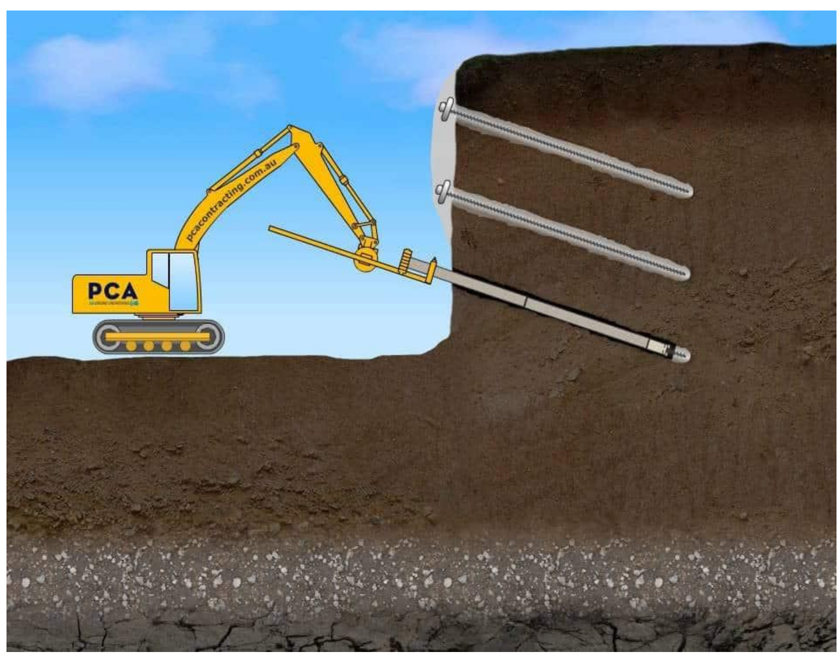
Clay and silt are especially vulnerable if they're saturated since they liquefy easily. However, anywhere that has a high water table or shows signs of being marshy are potentially vulnerable, and piling should be considered.

SOIL NAILING:

Principle:

The rods are passive reinforcement which, when the excavated face begins to strain, generate tensile forces and shearing resistance to counter the yield of the soil. Faces of steep slopes are usually protected by application of shotcrete, concrete so as to grout the reinforcing steel or nails. These provide stability to the steep soil slope.

For shallower reinforced slopes, the surface can be protected by mesh reinforcement. Soil nailing is used to stabilize the slopes or excavations where required slopes for excavation cannot be provided due to space constraints and construction of retaining wall is not feasible. It is just an alternate to retaining wall structures



DRAWBACK:

1. They are not good for high-water-table locations.
2. Extremely increased soil nail density may be required in low shear strength soils.
3. They are not appropriate for long-term usage in delicate and expanding soils.
4. Specialized contractors are needed.
5. It is possible that extensive 3D modelling will be necessary.

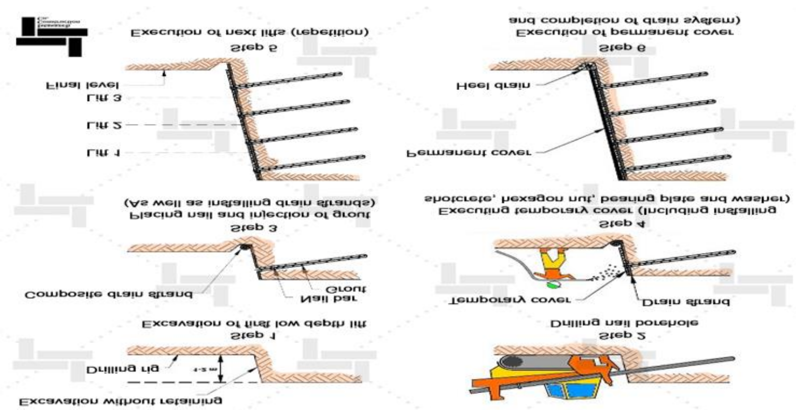
SOIL NAILLING TECHNIQUE:

In this technique, soil is reinforced with slender elements such as reinforcing bars which are called as nails as illustrated in Fig.1. These reinforcing bars are installed into pre-drilled holes and then grouted. Moreover, these nails are installed at an inclination of 10 to 20 degrees with vertical.

As the excavation proceeds, the shotcrete, concrete or other grouting materials are applied on the excavation face to grout the reinforcing steel or nails. Fig.2 to Fig.5 illustrate typical soil nailing process.c

CONSTRUCTION PROCEDURE:

1. *Excavation. The depth of the initial excavation lift (unsupported cut) may range between 2.5 and 7 ft, but is typically 3 to 5 ft and reaches slightly below the elevation where the first row of nails will be installed. The feasibility of this step is critical because the excavation face must have the ability to remain unsupported, until the nails and initial face are installed, typically one to two days. The type of soil that is excavated may limit the depth of the excavation lift. The excavated platform must be of sufficient width to provide safe access for the soil nail installation equipment.*
2. *Drilling of Nail Holes. Drill holes are advanced using specialized drilling equipment operated from the excavated platform. The drill holes typically remain unsupported.*
3. *A) Nail Installation and Grouting. Tendons are placed in the drilled hole. A tremie grout pipe is inserted in the drill hole along with the tendon; and the hole is filled with grout, placed under gravity or a nominal, low pressure (less than 5 to 10 psi). If hollow bars are used, the drilling and grouting take place in one operation.*
   B) Installation of Strip Drains. Strip drains are installed on the excavation face, continuously from the top of the excavation to slightly below the bottom of the excavation. The strip drains are placed between adjacent nails and are unrolled down to the next excavation lift.
4. *Construction of Initial Shotcrete Facing. Before the next lift of soil is excavated, an initial facing is applied to the unsupported cut. The initial facing typically consists of a lightly reinforced 4-in. thick shotcrete layer. The reinforcement includes welded-wire mesh (WWM), which is placed in the middle of the*



facing thickness . Horizontal and vertical bars are also placed around the nail heads for bending resistance. As the shotcrete starts to cure, a steel bearing plate is placed over the tendon that is protruding from the drill hole. The bearing plate is lightly pressed into the fresh shotcrete. Hex nuts and washers are then installed to engage the nail head against the bearing plate. The hex nut is wrench-tightened within 24 hours of the placement of the initial shotcrete. Testing of some of the installed nails to proof-load their capacity or to verify the load-specified criterion may be performed before proceeding with the next excavation lift. The shotcrete should attain its minimum specified 3-day compressive strength before proceeding with subsequent excavation lifts. For planning purposes, the curing period of the shotcrete should be considered 72 hours.

5. *Construction of Subsequent Levels. Steps 1 through 4 are repeated for the remaining excavation lifts. At each excavation lift, the strip* drain is unrolled downward to the subsequent lift. A new panel of WWM is then placed overlapping at least one full mesh cell with the WWM panel above. The temporary shotcrete is continued with the previous shotcrete lift.
6. Construction of Final Facing. After the bottom of the excavation is reached and nails are installed and tested, the final facing is constructed. The final facing may consist of CIP reinforced concrete, reinforced shotcrete, or prefabricated panels. Weep holes, a foot drain, and drainage ditches are then installed to discharge water that may collect in the continuous strip drain.

APPLICABLE SOIL TYPE:

Soil nailing can be applied for different soil types like glacial soils, sandy clays, clayey silts, gravels, etc.

But it is not suitable for loose granular soils, high corrosive soils, soft fine-grained soils, organic soils, etc.

Ground Improvement Technique

Ground Improvement is the application of various geotechnical techniques that are used to re-engineer existing soils to improve their engineering characteristics

The varies types of techniques are:

- Prefabricated Dynamic Compaction.
- Jet Grouting.
- Deep Soil Mixing.
- Ground Freezing.
- Lime Stabilization.
- Vertical Drains (PVDs

Introduction of PVD

Prefabricated Vertical Drains (PVDs) or 'Wick Drains' are composed of a plastic core encased by a geotextile for the purpose of expediting consolidation of slow draining soils. They are typically coupled with surcharging to expedite preconstruction soil consolidation. Surcharging means to pre-load soft soils by applying a temporary load to the ground that exerts stress of usually equivalent or greater magnitude than the anticipated design stresses. The surcharge will increase pore water pressures initially, but with time the water will drain away and the soil voids will compress. These prefabricated wick drains are used to shorten pore water travel distance, reducing the preloading time. The intent is to accelerate primary settlement. Pore water will flow laterally to the nearest drain, as opposed to vertical flow to an underlying or overlying drainage layer. The drain flow is a result from the pressures generated in the pore water.

- **Drain Features**

- PVDs have a channeled or studded plastic core wrapped with a geotextile. The plastic core functions as support for the filter fabric, and provides longitudinal flow paths along the drain length. It also provides resistance to longitudinal stretching as well as buckling of the drain. The drain jacket acts as a filter to limit the

Advantages and Disadvantages of Wick Drains

Advantages:

- Decrease overall time required for completion of primary consolidation due to preloading
- Decrease the amount of surcharge required to achieve the desired amount of precompression in the given time

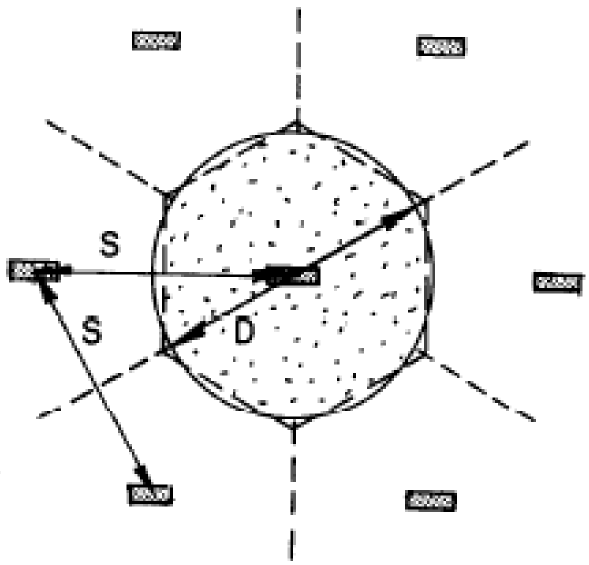
- Increase the rate of strength gain due to consolidation of soft soils when stability is of concern
- Comparison to sand drains:
- Economic competitiveness, less disturbance to the soil mass compared to displacement sand drains, and the speed and simplicity of installation. Also feasible to be installed in a nonvertical orientation

Disadvantages

- If the compression layer is overlain by dense fills or sands, very stiff clay or other obstructions, drain installation could require predrilling, jetting, and/or use of a vibratory hammer, or may not even be feasible
  - Under such conditions, general pre-excavation can be performed if appropriate
- Where sensitive soils are present or where stability is of concern, disturbance of the soil due to drain installation may not be tolerable
  - In such cases, sand drains installed by non-displacement methods or an alternate soil improvement technique may be more practical

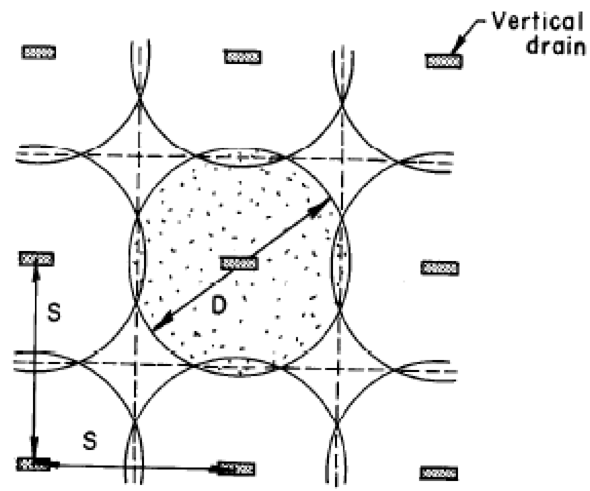
Drain Influence Zone

The drain influence zone (D) is a function of drain spacing (S) only. Vertical drains are commonly installed in square of triangular patterns. Square pattern layouts have greater ease and control in the field. However the triangular patterns are preferred to provide more uniform consolidation between drains.



D = 1.05 S

TRIANGULAR PATTERN



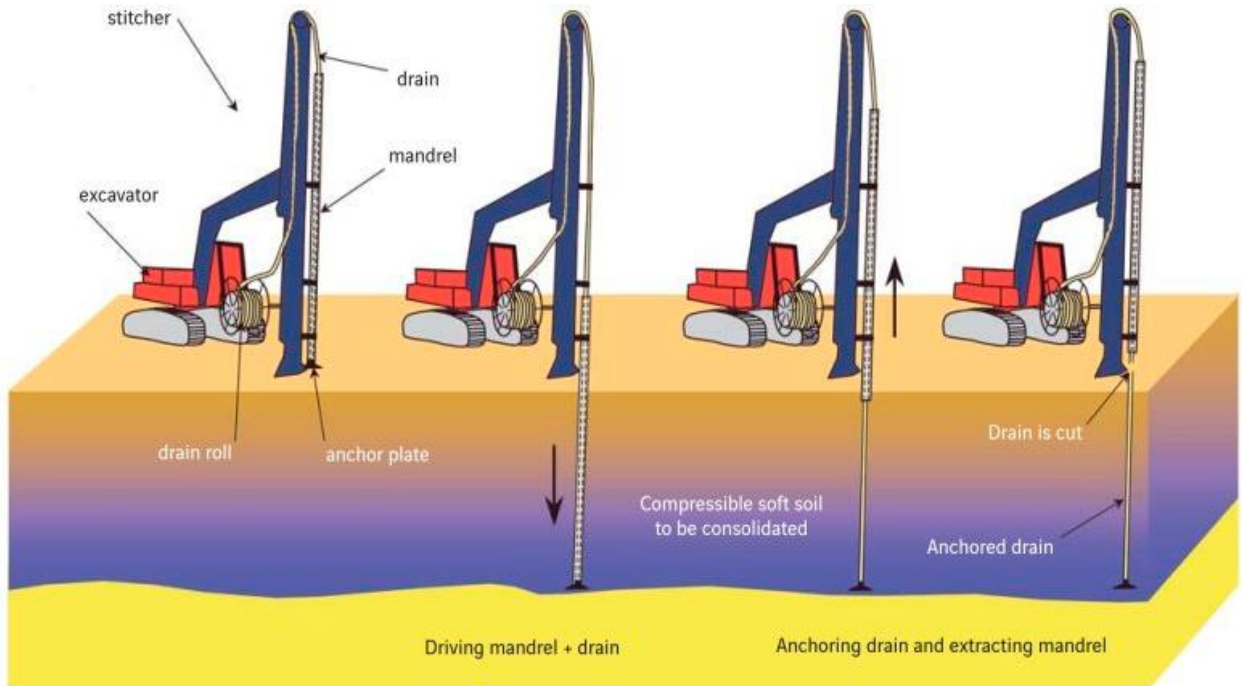
D = 1.13 S

SQUARE PATTERN

- **Suitable Soils**
- It is commonly assumed that wick drains should be used in all soils that compress very slowly under natural drainage condition due to low soil permeability and relatively great distance between natural drainage boundaries. However, PVD are not versatile for all soil types and geological conditions. The drains can be implemented in soils that are moderately to highly compressible under static loading. Applicable soils include:
- Inorganic silts and clays of low to moderate sensitivity
- Organic layers
- Decomposed peat
- Clayey and silty sands
- Dredge spoils

- Varved cohesive deposits

INSTALATION:



Comparative Study of ground improvement technique

	Stone column	Micro Pile	Soil Nailing	PVD
Applicability	Like most ground improvement techniques, stone columns are used to reduce settlement and increase load-bearing capacity. They also accelerate soil consolidation as a result of the drainage capacity of the granular material within the columns, which act as pore or water pressure evacuation points.	Micro piles can be employed in almost any subsurface soil or rock since they can be inserted using drilling equipment and combined with various grouting procedures to form the bearing element. The bearing soil or rock will determine their load carrying capacity	Soil nailing is a ground stabilisation technique used to reinforce and strengthen existing ground. It can be used on either natural or excavated slopes. It involves drilling holes for steel bars to be inserted into a slope face which are then grouted in place. It is economical and also applicable in seismic zones.	Prefabricated wick drains are used to shorten pore water travel distance, reducing the preloading time. The intent is to accelerate primary settlement. Pore water will flow laterally to the nearest drain, as opposed to vertical flow to an underlying or overlying drainage layer
Soil	Stone columns are best suited to sandy soils. A greater concentration of stone columns are required in siltier soils.	Micro Pile can be installed in almost any type of soil, and even rock	Soil nailing can be applied for different soil types like glacial soils, sandy clays, clayey silts, gravels, etc. But it is not suitable for loose granular soils, highly corrosive soils, soft fine-grained soils, organic soils, etc	applied in areas with compressible and water saturated soils such as clay and silty clays.
Costing	Stone columns are typically the cheaper of these ground improvement techniques	Micro pile construction is much more costly	Soil Nailing construction cost is also high depending the complexity of the work.	Construction of PVD is much more high as compare to others ground improvement technique because this technique is totally involved machinery , which is costly.
Labour	Required both skilled and unskilled labor	**labor and supervision, and manufacturing techniques** required **for design, installation and testing of micro piles**	Required skilled as well as unskilled labor.	Required skilled as well as unskilled labor labor

<u>Stone column</u>

Installation of stone column improves ground by reducing soil settlement. Due to its higher modulus of elasticity than that of soil, it absorbs more load than soil and reduces overall settlement.
Since applied load distributes in between soil and stone column in the ratio of their stiffness, the

load carrying capacity of soil also increases.
Stone aggregates are used to fill stone column. Water can easily pass into the stone column. So, stone column helps in excess pore water pressure mitigation and accelerates the consolidation process.
In this method, boring is done by displacing nearby soil. The soil is displaced laterally, due to which engineering property of soil gets change.

Micro Pile

Micro-piles are piles molded on the spot to serve as deep foundations and highly tensioned stress along the shaft, composed of sand and cement mortar and thoroughly reinforced throughout its length. Micro-piles are employed in highly compact or consistent ground or in the ground where bedrock or rocky formations are found, in which excavating may only take place with the use of rotating hydraulic drills. They may be placed in an inclined position. Micro-piles are also known as pin piles, needle piles, and root piles

Soil nailing

Soil nailing is a ground stabilisation technique used to reinforce and strengthen existing ground. It can be used on either natural or excavated slopes. It involves drilling holes for steel bars to be inserted into a slope face which are then grouted in place. It is economical and also applicable in seismic zones. Increases shear strength of overall soil mass and can be used in wide soil types.

PVD

Prefabricated Vertical Drains (PVDs) or 'Wick Drains' are composed of a plastic core encased by a geotextile for the purpose of expediting consolidation of slow draining soils. They are typically coupled with surcharging to expedite preconstruction soil consolidation. Surcharging means to pre-load soft soils by applying a temporary load to the ground that exerts stress of usually equivalent or greater magnitude than the anticipated design stresses. The surcharge will increase pore water pressures initially, but with time the water will drain away and the soil voids will compress. These prefabricated wick drains are used to shorten pore water travel distance, reducing the preloading time. The intent is to accelerate primary settlement. Pore water will flow laterally to the nearest drain, as opposed to vertical flow to an underlying or overlying drainage layer. The drain flow is a result from the pressures generated in the pore water. Figure 2 below demonstrate vertical water flow without the use of prefabricated wick drains, and horizontal water flow with the use of wick drains. Prefabricated Vertical Drains (PVDs) or 'Wick Drains' are composed of a plastic core encased by a geotextile for the purpose of expediting consolidation of slow draining soils. They are typically coupled with surcharging to expedite preconstruction soil consolidation. Surcharging means to pre-load soft soils by applying a temporary load to the ground that exerts stress of usually equivalent or greater magnitude than the anticipated design stresses. The surcharge will increase pore water pressures initially, but with time the water will drain away and the soil voids will compress. These prefabricated wick drains are used to shorten pore water travel distance, reducing the preloading time. The intent is to accelerate primary settlement. Pore water will flow laterally to the nearest drain, as opposed to vertical flow to an underlying or overlying drainage layer. The drain flow is a result from the pressures generated in the pore water. Figure 2 below demonstrate vertical water flow without the use of prefabricated wick drains, and horizontal water flow with the use of wick drains.