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Santosh Tekkannavar
Department of Civil Engineering, Ramaiah Institute of Technology, Bengaluru, Karnataka, India,
santoshtekkannavar@gmail.com

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Time Motion Study on Soil Protection Works

Santosh Tekkannavar

Department of Civil Engineering, Ramaiah Institute of Technology, Bengaluru, Karnataka, India
E-mail: santoshtekkannavar@gmail.com

Abstract- *Soil protection works have become popular due to their immense contribution to protecting the building from land sliding. A building structure requires a stable foundation to ensure best construction and durability. There are various engineering techniques in soil protection works, this paper consists of the Soil nailing procedure adopted in the Northwest Commercial multi-use (NWCM) Project of Karle Infra Pvt. Ltd Company, currently executed by the vendor Geoengineering Pvt. Ltd. Soil nailing technique is used to stabilize the existing slope and construct retaining walls from top down. Steel nails are used as a reinforcement of soil which are drilled and grouted into the soil to create a compound mass similar to a gravity wall. The Soil nailing procedure is an alleviative measure to handle unstable natural soil slopes or unstable filled slopes. Soil protection works include multiple activities that occur in a systematic and sequential manner. The critical activities influencing the duration, schedule and progress of soil protection works are identified and a time-motion study is used as a tool to identify the difference in productivity to improve the progress of the soil protection work. Each activity of grouted nailing for one lift of excavation is carefully analyzed to record the time spent for that activity and to identify areas to reduce time and increase efficiency. The study can improve planning work based on the actual duration of activities identified and help to minimize delays at the construction site.*

Keywords - *Soil Protection, Time-motion study, Soil stabilization, Soil nailing, Grouted nailing, productivity, soil protection works.*

I. INTRODUCTION

The soil protection work is done to control the active slope of the soil surface whenever there is a requirement of a deep foundation for the structure. The soil nailing procedure has gained traction for permanent and temporary slope strengthening activities at both in-situ cut slopes of any formations and man-made filled slopes. The soil stabilization which includes micro piling, soil nailing, grouted nailing mentioned in coming chapters is adopted in the North West Commercial multi-use (NWCM) Project located near 100ft road Kempapura, Veeranapalya, Hebbal, Bengaluru. The site has a lake waterbody nearby on one side within a proximity of 50 m and on other sides it is surrounded by land parcels. The time-motion study is done for the activities involved in micro piling and soil nailing. The time-motion study is the systematic observation of a particular activity to improve productivity. Productivity is the measure of work done per person/machinery per day. The soil nailing works depend on the soil types as different soils require different strengthening procedures.

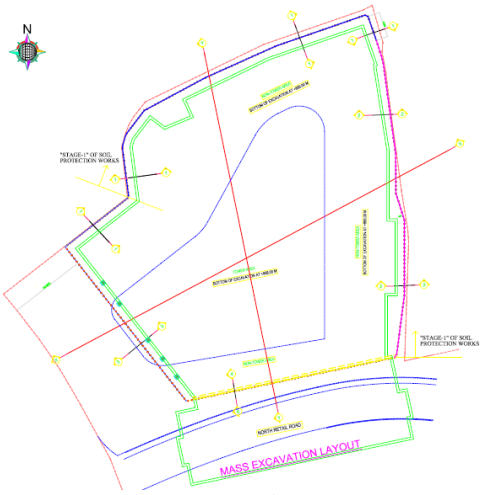

Figure 1: Layout of NWCM Site

A. SUITABILITY OF SOIL NAILING AND MICROPILING CONCERNING DIFFERENT TYPES OF SOIL

In soil nail construction, there is a requirement of temporary stability in both excavations which is done in stages and the drilled holes. The soils with adequate temporary self-support of sub-vertical height of about 2m for a minimum of 1 to 2 days and stability of hole for least of four hours are considered apt for ground for soil nailing. (Shaw-Shong., 2005)

The following types of soil would be suitable for soil nailing given the aforementioned requirements:

- Cohesive, stiff, fine soils
- Soils containing cemented granules
- granular soils that have been properly graded and have an adequate moisture content and apparent cohesiveness of at least 5 kPa.
- The majority of extra soils and weathered rock mass do not have unfavorable geological settings (such as discontinuity of weak daylighting, extremely fractured rock compound mass, etc.) during the excavation, exposing the land above the groundwater table.

The following are the main effects of soil nailing work under inadequate ground conditions:

i. Grout loss via the fragmented rock compound mass, wide open joints, and cavities
ii. Collapsing of drilled hole
iii. Inadequate resistance at the soil-to-nail interface because of hole-drilling disruption.
iv. Localized face stability.

II. CONSTRUCTION ASPECTS OF MICROPILING, SOILNAILING, GROUTED NAILING.

1. METHOD STATEMENT

It is crucial that the method statement outlining how the work will be completed in accordance with the requirements of the specification, the contracting companies' contractual obligations, and the machinery or man power resources at his/her disposal is properly reviewed and supervised by the design consultant officially.

The classic method statement for micro piling, soil nailing and grouted nailing works shall include the following items:

1.1 MACHINERY

The following equipment is necessary for micro piling, soil nailing and grouted nailing works.

A. Micro piling Equipment

Micro piles are piles with smaller diameter which are often called mini piles, pin piles, needle piles or root piles, mostly a mini hydraulic hammer is used to install piles using percussion method. But it also depends on the type of micro pile such as driven micro pile, compaction grouted micro pile, post grouted micro pile and pressure grouted micro pile. (Riffin Bomic.R, 2016)

Figure *2: Micro piling machine*

B. Drilling Equipment

There are a few common types of drilling equipment, namely rotary air-flushed and water-flushed, down-the-hole hammer, and tri-cone bit. It is important to procure drilling equipment with sufficient power and rigid drill rods.

Figure 3: Wagon Quarry driller

C. Grout Mixing Equipment

For production of uniform grout mix, the high-speed shear colloidal mixer should be considered. To deliver grout mix uninterruptedly, a powerful grout pump is needed. In case the fine aggregate is considered as filler for the mix, a special grout pump shall be made use of.

Figure 4: Grout mixing equipment

D. Shotcreting / Guniting Equipment

To regulate the volume of water that is injected into the high-pressure flow motion of sand/cement mix while using the dry mix method, at the nozzle outlet a valve has to be installed. A measuring pin must be inserted to direct the nozzle worker at predetermined vertical and horizontal intervals in order to manage the shotcrete's thickness.

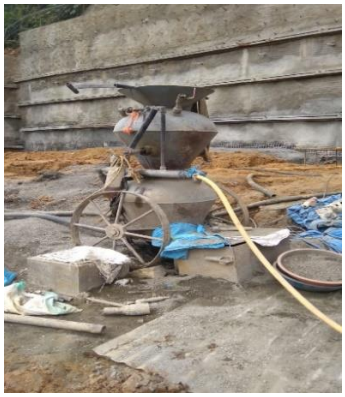

Figure 5: Shotcreting machine

E. Compressor

Shotcrete must be delivered by the compressor at a minimum rate of 9m 3 per minute. If the work is being done close to a housing estate, hospital, or school, compressor's loudness may occasionally be a problem.

Figure 6: Compressor

1.2 MATERIAL

A. Steel Reinforcements

Galvanization is required for all steel components to prevent corrosion. Under unavoidable situations where there is machine threading after galvanization, then the thread must receive the appropriate zinc-based coating. The PVC corrugated pipe used should be of high quality and have enough thickness for double corrosion protection. Galvanized corrugated drill rod can be used if possible.

The structural steel of 16mm Φ for soil nailing and 25mm Φ for grouted nailing are used. ISMC 200 for caping beam and ISMC 150 for waler beam.

B. Concrete

The Grouting around annular space of 200 mm dia micropiles and followed by concreting of the micro pile using Ready mix concrete is carried out, each pile takes around 0.6-0.8 cum of M25 concrete.

C. Grout Mix

For standard soil nails, the grout mix has a water-cement ratio ranges from 0.4 to 0.5. To reduce grout shrinkage and breeding, as most cementitious grout will experience some grout shrinkage, some non-shrink additives can be used. When the grout shrinks, the resistance will be significantly reduced at the grout-soil interface of the nail.

D. Shotcrete/Gunite

A continuous flow of mortar or concrete mixtures that are sprayed or pneumatically blown at high velocity perpendicularly into the exposed ground surface is known as shotcrete, also known as gunite. Self-compacted cementitious mortal can be created as the facing using high-speed shot mortal or concrete. The operator's subjective addition of water to the nozzle causes the water-cement ratio to fluctuate, which is the only downside of this technology. Shotcrete mixtures generally have a water-to-cement ratio of 0.35 to 0.5. Shotcrete can be cured using a wet gunny sack or chemical curing agent. Admixture can occasionally be used to shorten the shotcrete's setting period. Before receiving the shotcrete, the ground surface must be prepared. Generally speaking, the surface trimming must be done to an adequately smooth surface that is free of seepage and loose debris. The soil and shotcrete beneath the ground surface must remain in a balance in terms of moisture.

1.3 MAN-POWER

A team of approximately four workers for drilling (1 rig operator, 1 helper to control the compressor) and 2 helpers to join/dismantle drill rods and change bits, a team of three workers for grouting (2 for batching and mixing cementitious grout and 1 to control the grout pump), and a team of six workers for shotcreting will make up the working team for the entire grouted nailing project (1 nozzle man, 4 for batching cement and aggregates, and 1 for controlling delivery system)

Table 1: Manpower details

Team	Details	Nos	Total Nos/team
Drilling	Power rig operator	1	4
	Helpers – to join/dismantle drill rods and change bits	2	
	Compressor controller	1	
Grouting	Workers for batching and mixing cementitious grout	2	3
	Grout pump controller	1	
Shotcreting	Nozzle man	1	6
	Workers for batching cement and aggregates	4	
	Worker to control delivery system	1	

Soil nailing activity obviously requires a great degree of coordination and competence. Shotcrete quality is governed by nozzle man in terms of both aesthetics and structural needs. It is challenging to guarantee a high-quality product in the absence of skilled and experienced staff.

III. CONSTRUCTION SEQUENCE

Soil stabilization includes micro piling, soil nailing, and grouted nailing. below are the details of the construction sequence:

A. Micro piling

It involves cleaning the area and marking the position of the micro pile. The drilling of the bore takes place for a length of 6m, next followed by insertion of the casing and grouting of it. Concreting is carried out using the Ready-mix concrete. After completion of more than 10 micro piles, each micro pile is connected using caping beam of ISMC 200.).

B. Soil nailing

After the initial excavation up to a depth of 3m below the Ground Level (GL), the platform preparation for soil nailing followed by dressing is carried out. Once the completion of dressing, mesh fixing is done to stable the soil from sliding due to nailing of 16mm Φ of 6m in length at 15-degree inclination downwards. The shotcreting is carried out after the nailing activity.

C. Grouted nailing

After the approx. depth of 3m, the construction cycle of soil grouted nailing can be segmented into the following activities:

- Initial excavation

The original ground profile is trimmed to the working platform level, where the first row of soil nails may effectively be put, will be done during this initial excavation. The surface that is trimmed should be able to support itself until the activity of installing nails is finished as a condition of this temporary excavation. Sectional excavation can occasionally be done for soil that has a quick self-support time. The trimmed surface must be in a good enough state to receive the shotcrete if it is intended to be used as a facing element. The excavation for one row is done for a depth of 2m, including an additional 0.5 m for waler beam activity, as each lift is 1.5m in most of the stretches.

- Dressing

It contains an additional 0.5m allocation for the subsequent set of activities after the excavation for the lift is finished. Dressing is carried out manually to facilitate both the drilling of the hole and the fitting of the mesh.

- Drilling of holes

Depending on the state of the ground, drilling can be done by rotary wash boring, auguring, or air-flushed percussion drilling. The size of the drilled hole must match the planned dimensions. The size of hole can usually range from 100mm to 150mm. The drill hole is often slanted at a 30-degree downward angle from the horizontal to contain the grout. Prior to nail insertion, any potential collapsed materials must be removed using air or water to prevent a reduction of resistance in the interface between grout and ground.

- Insertion of nail reinforcement and grouting

Initially, there is preparation of nails with adequate centralizers at adequate spacing and for suitable grout cover for the first and foremost defense of corrosion protection. Besides, for durability, galvanization and pre-grouted nail encapsulated with corrugated pipe can be considered. A grouting pipe is traditionally attached with the nail reinforcement while inserting the nail into the drilled hole. The nail is driven into the surface at 10-12 bar pressure. Grouting is done from the bottom up until fresh grout returns from the hole are observed. The conventional range of water to cement ratio of the typical grout mix is from 0.45 to 0.5. The non-shrink admixture utilized is Cebax, the grouting is done under the pressure of 1bar. A time-motion study on the Grouted nailing is briefed in coming chapters.

IV. SCHEDULE OF WORK

The below table consists of the group of activities for west stretch lift-4, The similar activities are repeated in all the stretches until the 4-basement plan is reached. The table consists of activity of the lift, planned productivity and its duration.

Table 2: Schedule of work

Activity	UOM	Qty	Productivity planned		Duration
Excavation of lift 4	cum	577	500	Cum/day	2
Grouted Nailing of Lift 4					7
Dressing	Sqm	48	50	Sqm/day	1
Drilling & Nailing 25mm dia 12m length -1m c/c	Nos	49	15	nos/day	3
Grouting 25mm dia 12m length	Nos	49	15	nos/day	3
Waler beam - 2 MC 150	Rmt	48	18	rmt/day	3
Mesh Fixing	Sqm	48	50	Sqm/day	1
Shotcreting of 50mm	Sqm	48	50	Sqm/day	1

- Waler beam

Once the Grouted nailing activity is done, the succeeding activity simultaneously is the fixing of the waler beam activity. This involves aligning of ISMC 150 & ISMC175(Some cases) and welding the joint between 4 waler beams (2 of the beams will be Overlapped) as the single waler beam is of 6m, the joint consists of batten plate, Flange plate & web plate welded to that joint, these are called MS plates.

- Weep holes

To decrease the soil pressure exerted, weep holes are drilled into the surface at 2x2 m-c/c, the weep holes are of 50Φ and 2m of length. The wagon driller machine is used to drill the hole and a 2m length of pipe is inserted into that hole at a 10-degree in the upward direction.

- Mesh fixing

It entails attaching the 75x75x4.2 mm mesh to the finished surface. The mesh is 1.5 meters deep and has a running meter of 15 meters. Utilizing 10 mm U clamps buried 300 mm into the soil layer and welded to driven nails, the 15 m mesh is bent and fastened to the surface. If there is an excessive void between the mesh and dressed soil layer, shattered stone fragments are used to fill the void.

- Shotcreting of 50mm

After mesh fixing is concluded, the surface is sprayed with a mix design ratio of cement: Sand: Aggregate = 1:2:1 at a pressure of 7-8 bar. The thickness of 50mm is done on average but it varies with site conditions and the kind of dressing finish.

V. PURPOSE OF TIME-MOTION STUDY

In order to determine the standard time required for completing a particular activity. The activities mentioned in previous sections are the main constituents of the soil protection works for the North West Commercial Multiuse (NWCM) project. The crucial part of this process is Grouted nailing because it directly influences the next set of activities and the scheduled finish of the complete soil protection works. Hence grouted nailing was considered a crucial activity, and the need for improving its productivity of it can directly help in getting back the project on schedule in the case of delays.

There are many tools for improving the productivity of the activity, the time-motion study is one of the tools to understand the exact time for each performance so that the activity can be improved at the root. (Aft, 2001)

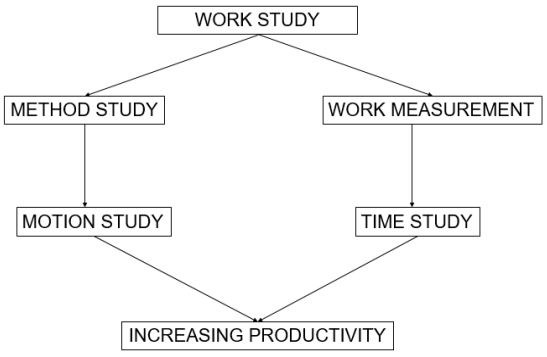

Figure 7: Time motion study flow chart

VI. TIME MOTION STUDY OF GROUTED NAILING ACTIVITY

Time motion study involves systematic observation, analysis, and quantification/measurement of the separate steps in the performance of a specific activity or task for the objective of establishing a standard time for each performance, improving procedures, and increasing productivity. This Grouted nailing activity involves drilling 150mm Φ holes of 25mm rods at 2m-c/c in a 30-degree slope downwards. The wagon drilling machine is used to drill the holes of the required Φ and slope. The drill rod used to drill the hole is of Φ 3 inches =7.62cm, and is of length 3m. As we need a total of 12m deep hole, hence 4 numbers of drill rods are used to obtain the required depth.

- INITIAL STAGE

setting the compressor motor and wagon driller machine for the entire day's work. The engine and pond are set up during this activity, which is the first portion of the drilling and nailing activity. The Pond serves as a holding area. Through pipelines carrying water, the water from the pond is connected to the drill rod. As the water exits the jack, it causes the earth to become loose and fall out, creating a hole. Depending on how easily you can get between the stretches, this setup activity lasts between 30 and 60 minutes. Normally, it takes 45 minutes, but the west stretch lift-4's drilling and installation took about 60 minutes.

Figure 8: Pond System

Figure 9: Compressor machine and pipes

- STEP-*1*

Drilling for the first hole's 3m in length commenced at 10:20 am and concluded at 10:40 am, meaning the first 3m of depth took 20 minutes.

Figure 10: Drilling of 1st hole

- INTERMEDIATE STEP

The preparation work for reaching the subsequent depth of 3m is being done at this time. The hole can be dug down to a total depth of 6 meters after step 2 is finished. Setting everything up took about 3 minutes. Prior to the next phase, there is this step. Workers walk around enough to set up during this intermediate step.

Figure 11: Intermediate step

- STEP-2

At 10:43 am, the hole was drilled to a depth of 3, and it was completed at 10:51 am. It lasted for 8 minutes. Before initiating step 3, the intermediate step lasted two minutes. A depth of 6 meters was reached completing this step. Only water emerges from the hole after 6 meters in depth, whereas soil does so up to this point.

Figure 12: Drilling of 2nd hole

- *S*TEP-3

The third hole's drilling process commenced at 10:53 am and was completed at 11:04 am. About 11 minutes passed. The intermediate stage of the fourth hole took two minutes.

Figure 13: Drilling of 3rd hole

- STEP-4

The final drill rod was drilled beginning at 11:06 am and finished at 11:18 am. It lasted for 12 minutes.

Figure 14: Drilling of 4th hole

- STEP-5

Following this, the inserted drill rods were removed from 11:18 am to 11:22 am (duration: 4 minutes), 11:22 am to 11:24 am (duration: 2 minutes), 11:24 am to 11:28 am (duration: 4 minutes), and the remaining drill rod was left in place for the following drilling point. It took about 3 minutes to reach the beginning of the following drilling location.

Figure 15: Removing of inserted pipes

A. SUMMARY OF TIME STUDY

The start time and end time for each phase of the grouted nailing operation are listed in the table below. The start time and end time are used to compute the duration.

Table 3: Summary of Time Study

Sl.no	Activity	Start Time	End Time	Duration (Min)
1.	Initial Stage-Positioning of wagon driller	9:20 AM	10:20 AM	00.40.00
2.	Drilling of 1st hole(3m)-0 to 3m	10:20 AM	10:40 AM	00.20.00
3.	Setting up for 2nd hole	10:40 AM	10:43 AM	00.03.00
4.	Drilling of 2nd hole(3m)-3m to 6m	10:43 AM	10:51 AM	00.08.00
5.	Setting up for 3rd hole	10:51 AM	10:53 AM	00.02.00
6.	Drilling of 3rd hole(3m)-6m to 9m	10:53 AM	11:05 AM	00.12.00
7.	Setting up for 4th hole	11:05 AM	11:06 AM	00.01.00
8.	Drilling of 4th hole(3m)-9m to 12m	11:06 AM	11:18 AM	00.12.00
9.	Removing of all the inserted pipes	11:18 AM	11:28 AM	00.10.00
10.	Positioning for drilling of next hole	11:28 AM	11:30 AM	00.02.00
11.	Inserting and grouting of 25m dia bar	11:28 AM	11:38 AM	00.10.00

B. CHALLENGES

This stretch of land has clay soil where the temporal motion investigation is being conducted. Drilling becomes challenging when clayey soil becomes entangled with the driller's cutting bit, frequently causing gear box and drilling machine chain failure. To continue working, the operator must weld the drilling machine's jack, and the gear box must be changed. Due to the fact that this activity involves the circulation of water and clayey soil has a cohesive quality, the soil gets sticky and motion of the operator and assistants crew becomes challenging.

VII. CONCLUSION

With the exception of the pre-stage of machine arrangement, which typically takes 45 minutes, the entire activity lasts roughly 68 minutes. The research done on time-motion is just one sample. It is necessary to gather more samples in order to identify the precise variables of such an activity. By making things simpler to attain the machinery setup, the initial stage time can be cut down. This research will indeed pave the way for the application of the time-motion study to boost productivity.

VIII. FUTURE SCOPE

This study is focused on a single sample; however, it can be used as a reference point for a subsequent time-motion analysis of grouted nailing activities to determine the precise variance and causes of the productivity decline. Therefore, the issues can be resolved in order to boost productivity. The samples can be taken from various stretches and according to the time when the work started. These data can be examined to determine a mean time and to reduce deviation from the mean at the root level in order to speed up the project's progress. If the proper data for all types of soil is made available, it can help in scheduling the project in a more realistic way. If there's a time limit to complete the work this data can give an appropriate way to help avoid the non-value added works and complete it within the schedule.

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