ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

EXECUTION MANAGEMENT OF DEEP EXCAVATION IN ADDIS ABABA CONSTRUCTION PROJECTS

BY SEMEGN W/YOHANNES

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SEMEGN W/YOHANNES

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Approved by Board of Examiners

Wubishet Jekale (Dr. Ing)_	______________________	___________________
Advisor	Signature	Date
______________________	______________________	___________________
External Examiner	Signature	Date
______________________	______________________	___________________
Internal Examiner	Signature	Date
______________________	______________________	___________________
Chairman	Signature	Date

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Abstract

To alleviate the traffic congestion of the A.A city, it is vital and crucial to allocate underpass and overpass transportation means for the expansion of roads and construction of supportive infrastructure. Although, the construction of high rise building are significantly increasing, especially by financial and commercial institutions as well as by other individual investors for hotel and real state purposes. Those buildings require large parking area, stores and other facilities that can only be alleviated by constructing basements. To construct basements and underground transportation means deep excavation is a must. Deep excavation is an important component of construction which relieves shortage of space and allows usage of underground spaces for different structures. Thus, this thesis is prepared to study practice of deep excavation in scientific way and to develop a better ways for execution of deep excavation in urban areas.

The research was undertaken to assess the practices in planning, quality assurance services and execution, identify challenges that need to be addressed and to recommend interventions in order to improve execution management of deep excavation in A.A. civil work projects. Accordingly, a literature review was conducted on related topics, through which numerous variables challenge was identified. In the matter of fact, detailed analyses were accomplished with primary data collected through questionnaire, interviews and by physical observation of projects.

The response are found from different professional found in employers, consultants and contractors side and which are engaged on the three civil work construction projects (i.e. building, road & railway). The responses are calculated by using a weight average technique of all groups as per each variable ranked. Based on the findings it is observed that, challenges as safety and health management, lack of recording construction events, wrong calculation of earth pressure and lack of well qualified and experienced professionals found to be the most common outstanding once. Failures encountered and observed from respondents are differential settlement, subsidence of ground, cracks on nearby structures and collapse on adjacent structures including small injuries up to loss of lives of workers and also neighboring community living on adjacent have been recorded & investigated.

Recommendations are forwarded by pointing out the responses & expectations from clients, consultants and contractors. Those recommendations cultivate us to adopt quality assurance by implementing recording and analyzing construction events with close supervision. During construction, monitoring execution compliance by regulatory bodies and upgrading professionals experience through continuous professional development trainings are deemed as remedial measure to execute fatal and hazard free deep excavation in A.A.

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Acronyms

A.A.	Addis Ababa
AACRA	Addis Ababa City Road Authority
AALRT	Addis Ababa Light Railway Transit
ACI	American Concrete Institute
BS	British Standard
DIN	Deutsche Industrie Norm
ES	European Standard
TSC	Traffic and Safety Coordinator
BATCODA	Ethiopian Building and Transport Construction Design Authority
ERA	Ethiopian Roads Authority
FHWA	Federal Highway Agency
FIDIC	Federation Internationale des Ingenieurs – Conseils, a French acronym with its English equivalent of “International Federation of Consulting Engineers”
RII	Relative Importance Index
WBS	Work Breakdown Structure

1. Introduction

1.1. Background

A rapid development of economy leads for further construction of infrastructures while the available construction areas are limited. Thus the construction requires much excavation for basement and underpass road provision that embrace difficult design, complicated construction technology, vulnerability to circumstance and other complex characteristics. [23]

Deep excavation into the ground is indispensable to create additional floor space and roads to meet increasing space requirements for parking and other functions in multi-story buildings and for underpass ways at the city centers. Numbers of deep excavation pits in city centers are increasing every year. Structures in the immediate vicinity of excavations, dense traffic scenario, presence of underground obstructions and utilities have made excavations a difficult task to execute. An excavation is basic phase in the construction of basement and underpass infrastructures. The process of an excavation may encounter different kinds of soils underneath the same excavation site from soft clay to hard rocks. During excavation, some soil types pose greater problems than the others. [1,7]

No matter how many trenching, shoring, and back filling have been done in the past, as we all understand every project have its own unique characteristics, though it is important to approach each new project with the utmost care and preparation. Many on site accidents result directly from inadequate initial planning. Waiting until the work has started to correct mistakes in shoring or sloping slows down the operation, adds to the cost, and increases the possibility of other excavation failure. Determination of site condition through site observation, test borings for soil type or conditions, and consultations with local officials and utility companies is important and should be the primary activities to manage difficulties related to deep excavation. [1,5,6]

The goal of monitoring data management is to provide useful scientific information about the status and trends of various factors affecting the environmental impact of a project. Comprehensive data management functionality is thus essential for achieving this goal, particularly for urban deep excavations. [14]

But, it is not to be denied that design and construction of deep excavation becomes more difficult as excavation depth is deeper and surrounding environment becomes more complicated. Therefore, the construction project team must consider a wide variety of information to assess environment impact when managing risks and making project decisions. [21]

The thesis was originally undertaken to assess the practices in planning, execution with quality assurance services management, identify challenges that need to be addressed in recently constructed deep excavation projects in A.A. After analyzing the gathered information, remedial means have been included through conclusion and recommendations in order to improve execution management of deep excavation for the construction of basement and underpass roads in Addis Ababa construction projects.

1.2. Statement of the Problem

In our country cities develop rapidly with construction which makes the space above ground to become more & more precious. Due to this, underground space is developed with greater speed followed by deeper excavation although the existence of nearby structures makes the excavation work more challenging. Consequently, this part of construction requires special attention and management to avoid unplanned and unwanted result.

In most of local construction sites, during the execution of deep excavation sliding of the ground, getting unexpected substructure which have contrary characteristic to the geotechnical results, presence of unexpected water table, striking unknown utilities and so on makes the excavation more difficult. Also, because of negligence and less attention to safety and health, many accidents and injuries of workers can be incurred during deep excavation. This usually occurs due to less attention given to the execution management of deep excavation in construction.

Therefore, studying the current practice of deep excavation in local construction especially in Addis Ababa which leads to the above mentioned drawbacks and reviewing of regulations related to this issue is important to attain improved construction means.

1.3. Objective of the Study

The objectives for this research are:

- assessing local practices in planning, quality assurance services and execution of deep excavation for the construction of basement and underpass road works.
- identifying problems, challenges, unwanted effects and gaps that need to be addressed to improve the planning, quality assurance services and execution of deep excavation for the construction of basement and underpass road works.

- recommending interventions in order to improve the planning, quality assurance services and execution methodologies of deep excavations for the construction of basement and underpass road works based on the findings of the study.

1.4. Research Questions

This thesis will be guided by the following questions as major benchmarks:

1. What is the practice of Addis Ababa construction projects in the execution management of deep excavation work?
2. What are the problems and challenges incurred with regard to execution management of deep excavation?
3. How the gaps can be filled and improved methodologies can be achieve in order to have better execution management means?

1.5. Scope and Limitation of the Study

The scope of the study has been limited to projects which engage deep excavation and have been constructed in recent years. The projects are from the three type i.e. building, road and railway sectors. From the research building projects which there were three and more basement floors with underpass road and railway projects in Addis Ababa have been considered.

The data collection were limited to primary data i.e. observation, interviews & questioner mainly for the building & road sectors. There were difficulties to find relevant written and organized documents in every sector where deep excavation was implemented. Especially in railway project it was difficult to find even primary data through interviews & questioner since the companies weren't willing to give any kind of data. Thus, the availability of limited data precludes the researcher from further in-depth studying on the topic.

1.6. Significance of the Study

The expected outcomes of the study are:

- to contribute towards the improvement of deep excavation management;
- to contribute improvement mechanism of execution practice of deep excavation;

- to provide an input for contractors to have better execution mechanism
- to provide an input for controlling & supervision to regulatory bodies and consultants
- to show the challenges and failures that could occur due to poor execution and provide better mechanisms to alleviate them.

Therefore, the stakeholders who involve in the construction of deep excavation shall benefit from the outcomes of the thesis. It is also hoped that the findings of the research may simulate other researchers to conduct further studies.

1.7. Structure of the Thesis

This study has been organized into six chapters that discuss various aspects of the construction of deep excavation work that focuses on the main aspects which are of relevance to this thesis. Chapter one explains the background of the research and spells out what the research intends to achieve. It is followed by chapter two which is literature review of the thesis that provides a general understanding of international practice on the management of deep excavation and the challenges with the remedial measures are presented. This will also provide bases for the analysis of the main topics. In chapter three, the methodology used for the research are discussed and highlights of the primary and secondary data collection methods are given. Chapter four is dedicated to the analysis and discussion of the results obtained from the study. The last chapter draws conclusions of the research and provides some recommendations for improvement. Further recommendations for future studies are also included in this chapter. The following figure shows the organization and structure of the paper.

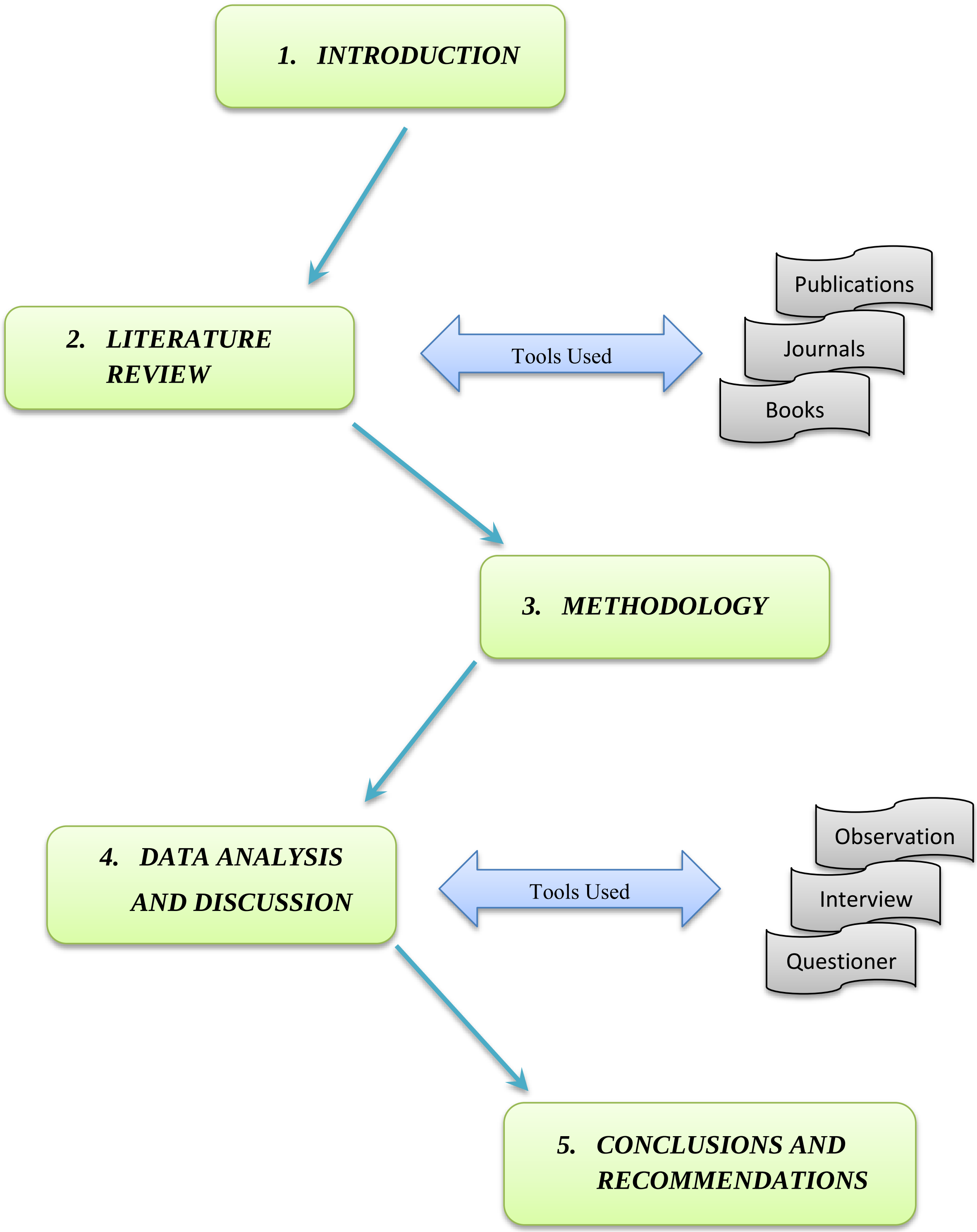


Figure 1.1:- Flow chart of the Research

2. LITERATURE REVIEW

2.1. General

In the construction industry, deep excavation works are becoming very popular as high rise buildings constructed and the creation of underground transportation increases. A deep excavation into the ground is indispensable to create additional space to meet increasing space requirements for parking of multi-story buildings and for underpass roads at the city centers. Numbers of deep excavation pits in city centers are increasing every year. Structures in the immediate vicinity of excavations, dense traffic scenario, presence of underground obstructions and utilities have made excavations a difficult task to execute. An excavation is basic phase in the construction of foundations, basements or underpass way. The process of an excavation may encounter different kinds of soils underneath the same excavation site from soft clay to hard rocks. During excavation, some soil types pose greater problems than the others. [1, 7]

It is not to be denied that design and construction of deep excavation becomes more difficult as excavation depth is deeper and surrounding environment becomes more complicated. Therefore, the construction project team must consider a wide variety of information to assess environment impact when managing risks and making project decisions. The goal of monitoring data management is to provide useful scientific information about the status and trends of various factors affecting the environmental impact of a project. Comprehensive data management functionality is thus essential for achieving this goal, particularly for urban deep excavations. [14, 21]

New construction with multi-story basements for parking and storage facilities calls for deep open excavation accompanied by the risk of damage to adjacent buildings. The drilling of the tiebacks supporting the structure, large displacement of the supporting wall due to unexpected high loads or driving of piles in the excavation and piping might create settlement and tilting of neighboring structures. [15]

Urban regeneration calls for travel to work and play, to offer and access services. However, the recent rate of growth in car travel is unsustainable. In order to reduce carbon dioxide emissions, other pollutants, traffic congestion and noise, car travel must be replaced by mass rapid transit systems. Cities around the world are attempting to regenerate or expand by building subways.

Increasing transportation needs the enlargement of existing railway or subway stations, underpinning and new construction works. In urban areas new public or private roads can be built underground and heterogeneous soils and nearby foundations of existing buildings may be encountered.

Concerning ground conditions, there is always an element of uncertainty; the ground is a natural product and can be investigated only in a limited number of drill-holes. On the other hand, the engineer must take into account these risks considering the characteristics of the subsoil and, without compromising cost. [15]

2.2. Process in Construction of Deep Excavation

As roots are base for the lives of trees, deep excavation construction is also the base for high rise buildings and underpass structures. In deep excavation construction work, there are various procedures, as per the literatures used and reviewed for the purpose of this research the main procedures can be categorized into three which are:

1. Planning,
2. Execution, and
3. Monitoring and Evaluation.

2.1.1. Planning

Excavation work should be carefully planned before work starts so that quality and safety can be assured and also efficient and effective utilization of resources within the schedule can be attained. It is imperative that preliminary analyses be carried out for many options of the walls, support systems and construction methods to assess on the cost and time of construction together with the technical requirements on the quality, safety and its influence on the adjacent structures before proceeding to the execution. [20]

In order to maintain quality for deep excavation work in urban area, planning of construction procedure, arrangement of site, locating of mobile equipment, stability of adjacent structures and similar issues shall be studied well. Thus, in the construction of deep excavation, planning shall focus the major concepts like design, quality assurance, presence and protection of nearby structure, safety and risks of the construction work, etc.

Planning involves identifying the hazards, assessing the risks and determining appropriate control measures in consultation with all relevant persons involved in the work, including the principal contractor, excavation contractor, designers and mobile plant operators. Structural or geotechnical engineers may also need to be consulted at this stage. Professional engineers must include a way for workers to enter and exit deep foundation excavations in their designs. [15, 16]

Excavation work is usually related to risk and the degree of risk increases as the excavation becomes deeper and as it is performed adjacent to existing structure so that risk management is mandatory. As Deltares developed the GeoQ method (Van Staveren, 2006) which is used to structure on ground related risk management. GeoQ is based on six generally accepted risk management steps:

1. **Determination of objectives and data collection**: it involves gathering of all relevant project information. It used to provide clarity about the project objectives which allows to define the risks as obstructions that prevent meeting objectives.
2. **Risk identification**: is an important step, and determines anything foreseeable that might obstruct the project objectives as a risk by giving a name and identity. However, large damage unfortunately result from unforeseen risks which remain as unforeseen. Thus our challenges remain to arrive at a maximum number of foreseeable risks and use different tools to identify them.
3. **Risk classification and quantification**: here risks are classified in terms of probability and consequences as the risk seriousness can be expressed in the likelihood or probability of occurrence and the likely effect or consequences of the risk. The classification can be as qualitative, semi-qualitative and quantitative.
4. **Risk remediation**: concerned with selection & application of remedial measures. Before engaging in the remedial action it is required to further breakdown and analyzing the risks by risk structuring and risk analysis. Then risk response strategies or remediation will be implemented.
5. **Risk evaluation**: in this step the objective is to verify whether the remaining risk profile is acceptable to the responsible and affected parties, or not. Means the risk response made needs to be checked and balanced with the risk tolerance of the affected parties.
6. **Transfer of risk information to next project phase**: all gathered and analyzed risk management information needs to be properly filled to transfer to the next project phase so that they can be used as basis for the risk management process of the next project. [4,23]

Therefore, in general terms for the management of deep excavation construction could encompass three main stages as risk identification, risk analysis, risk control and contingency plans of action, where the first stage presented in the planning category as follows.

Risk Identification

Many sources of risks in construction are associated with the construction of deep excavations. Ground movements, ground water control, and poor quality of construction are always main sources of risks in executing deep excavations.

Unavoidable induced ground movements are always associated with the stress release from the earthwork excavation within the site and this can result settlement of the ground. Other source of settlement could also occur due to the increases in the effective overburden pressure during lowering groundwater table in case of dewatering outside the excavation boundary. These ground movements could be predicted and controlled during the design process by adopting a finite element model by which the construction sequence is modeled and the ground movements are predicted. [22]

In another scenario, deep excavations must be designed in such a way that the elements of bracing system and neighboring structures meet both ultimate and serviceability limit state requirements. Also design and construction should be handled to avoid damage to neighboring structure that needs to consider legal requirements and necessary determination of impact zones and their environmental influence during execution and operation. [19]

Site investigation studies the presence of soil characterization, ground water conditions, underground utilities and other subsurface conditions. In the study of ground water conditions frequently report water in borehole logs but sometimes it may not be clear whether it is a water table, a perched level, a significant source of water, leakage from a water main, surface water infiltration or due to granular pockets and lenses. If there is plenty of water a watertight type of wall has to be selected otherwise water seeping through the wall is drained off. [18]

Technical data related to existing groundwater conditions should be investigated, and the need for groundwater control in making the excavation, planning a dewatering system to meet the job requirements and its effect on adjacent structures, specifications, monitoring and the necessity for recharge of the exterior water table should be assessed. Soil investigations generally includes determination of piezometric levels, presence of perched, depressed or artesian water levels, detailed description of soil layers, grain size analyses of aquifer soils. Depending on the project more detailed investigations may be made like borehole permeability tests, water pressure tests, well pumping tests and observation wells. Local studies on groundwater regime are also helpful if available. [18]

Every time workers must wear a full body harness inside a deep excavation attached to a secured lifeline that meets the requirements of the Workplace Safety and Health Regulation (relating to fall protection). The lifeline must extend to the top of the excavation and be secured to an anchor, as required by the regulation. A worker must be in place continuously to monitor the worker that is in the deep foundation excavation.

A tripod or similar type of hoist must be used to raise or lower workers into or out of deep foundation excavations. The hoist and all cables, hooks (equipped with positive means of securement) and components must be:

- designed and certified by a professional engineer
- inspected regularly to ensure safe operating condition
- a sufficient height to safely raise the worker completely above the ground surface
- equipped with a brake capable of supporting at least four times the maximum load that may be applied to it. [15]

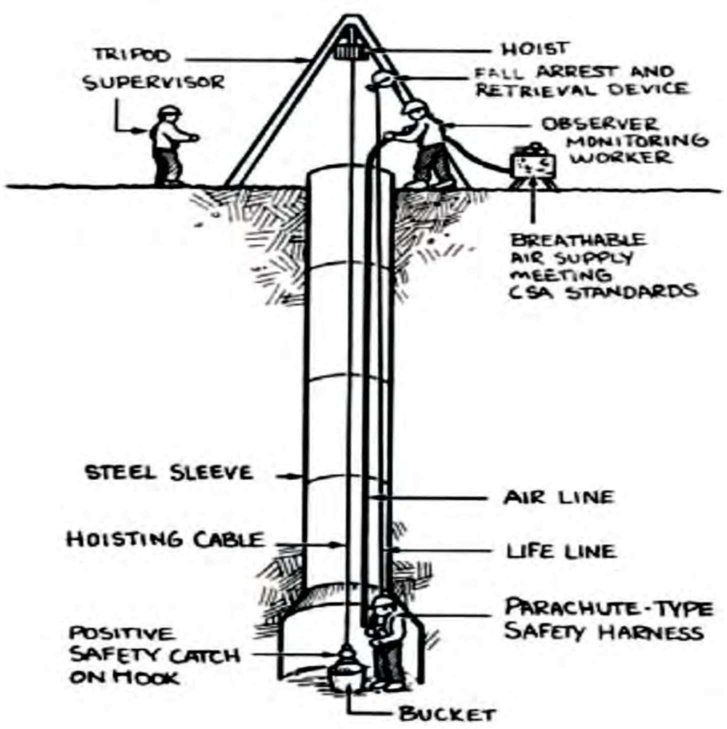


Figure: - 2.1 Tripod [15]

Concerning safety management of deep excavation safety and health regulation especially with respect to confined spaces must be followed. With respect to this, when workers are required to enter deep foundation excavations, support structures must be installed; that must be designed and certified by a professional engineer. The support structure must extend 300 millimeters (12 Inches) above the ground level and continue to the point where the work is being carried out. The support structure must be at least 700 millimeters (28 inches) in diameter and be secured against any movement.[15]

When one considers performing excavation of specific site conditions such safety checklist shall be well thought which are:

- Traffic,
- Proximity and physical conditions of nearby structures,
- Soil type,
- Surface and ground water,
- Location of the water table,
- Overhead and underground utilities, and
- Weather and so on.

These conditions can be determined through jobsite studies, observations, test borings for soil type or conditions, and consultations with local officials and utility companies to determine the approximate locations of utility installations. [1]

The other thing that must be studied before construction ahead is supporting wall. There are several types of in-situ walls are used to support excavations. The criteria for the selection of type of wall are size of excavation, ground conditions, groundwater level, vertical and horizontal displacements of adjacent ground and limitations of various structures, availability of construction cost, speed of work and others. One of the main decisions for the selection of supporting walls is the water-tightness. [1]

Major concern during the planning of deep excavation is the impact of construction related to ground movements on the adjacent properties and utilities. During excavation, the state stresses in the retained side are the stress relieve on the excavation face resulting in horizontal ground movement and follows by vertical movement for equilibrium and increase in vertical stress due to lowering of water table resulting in both immediate and consolidation settlement of the ground. These ground movements that vary away from the excavation can cause buildings, especially those on shallow foundation, to translate, rotate, deform, distort and finally sustain damage if the magnitude exceeded the tolerable limits. [20]

2.1.2. Execution

In particular in most modern development projects, the scale of construction tends to be growing bigger and bigger, that makes planning and construction of deep excavation become much more difficult and complex. The elements of a deep excavation are identified by means of a work-break-down-structure (WBS). For every element a list of unwanted events has been made. These unwanted events are described to show the relevance. In order to keep an overview, a differentiation has been made for unwanted events affecting

- Single elements of the deep excavation. e.g. instability of trench of cemented bentonite wall
- deep excavation as a whole, a combination of those single elements e.g. bursting/heave of a submerged concrete floor
- Surroundings of the deep excavation e.g. cracks in surrounding buildings caused by vibrating piles[4]

For a complete outline of all measurement techniques a risk based overview of a deep excavation is developed. This overview has the structure as shown below

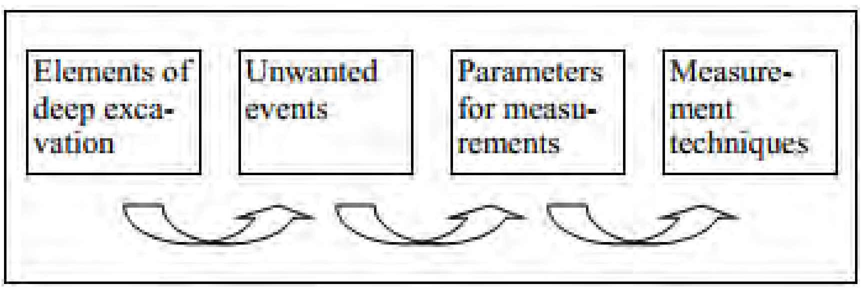


Figure 2.3:- Structure to identify measurement techniques [4]

For each unwanted event the parameters have been identified which should be taken into account for possible development of the unwanted event. With these parameters it is possible to find a list of specific measurement techniques. Each parameter and technique is described using standard. [6]

Deep excavation or basement or similar underground structures can be constructed using the following approaches:

1. Open cut arrangement
2. Bottom-up arrangement
3. Top-down arrangement

Table 2.1:- Comparison of approaches for deep excavation construction [17]

	Open cut	**Bottom-up**	**Top-down**
Size of Site	Very large open site	Small sized site	Large sized site
Site Environment	Unobstructed	Adoptable to most environment	Adoptable to most complex environment
Protection	Simplest protection	Complex lateral support required	Limited shoring support where required
Special Provision	Not much	Not much	Temporary vertical support required
Machinery Suitability	Large machine	Small machine	Large machine
Spoil Removal	Using ramp	Staged platform or bucket	Ramp vertical shaft or bucket required

In addition to what is explained in the table when certain jobs are simpler in nature the relative economical and effective way is cut & fill or bottom up methods, on the other side excavation is going deeper and the surrounding environment getting more complex and sensitive, top-down or combined method may be a more appropriate option to construct.[17]

It is important to carry out analyses to estimate the magnitude and distribution of the ground movements due to the proposed excavation of the nearby structure. Piled buildings adjacent to deep excavations have to be assessed differently from buildings with shallow foundations. Piled buildings settle an amount between the surface settlement (for friction piles in failure) and tip level settlement (for end bearing piles with sufficient capacity to take full negative skin friction). The precise soil-pile interaction can be estimated based on the pile load, the pile capacity and the shaft friction development. Based on measurements of timber pile foundations, the pile settlement is equal to the soil settlement at a depth of 0.3 – 0.8 times the pile length for most original timber pile foundations and 0.8-1.0 times the pile length for most renewed foundations in the first sand layer. Most of the modern buildings settle not more than the pile tip level. [13]

The other impact related to this construction work is environmental impact, which is usually related to displacements and strains caused by deep excavations. The most common are displacements of retaining structures and settlements of the adjacent buildings together with zones where they occurred. We can distinguish two types of environmental impact: natural influences (unloading, reloading and additional loading) and technological influences (related to technology applied and solutions). [19]

Natural impact: that includes changes of stress state in subsoil as a result of unloading process, and then loading by the structure. These influences are basically irrelevant to solutions used and technology of works applied.

Technological impact: depends on assumed solutions which influence the changes of stress state such as:

- type and technology of bracing system which define its stiffness,
- execution method of bracing,
- changes of stress state during the deepening process for diaphragm wall;
- type of support or anchoring (initial prestressing or strutting);
- vibrations during driving/vibrating of sheet pile wall;
- technology of excavation deepening;
- influence of excavation dewatering,
- disturbance of groundwater flow,
- soil improvement under neighboring structures,
- influence of vehicular traffic. [19]

While analyzing these specific situations one should take into consideration individual influences, which can occur, as well as corresponding to the impact zones. These zones must consider all the limitations resulting from:

- conditions of serviceability limit state for bracing
- system with supports and neighboring structures,
- character of nearby urban infrastructure and the impact on inhabitants and installations:
- vibrations (rate, frequency amplitudes),
- vertical displacements,
- horizontal displacements,
- difficulties for inhabitants.

Defining the range of impact zones as well as possible ground surface displacements behind the wall (especially positive displacements) one should take into account individual influences such as local conditions and experience. Since the methods defining range of impact zones and values of displacements are mainly based on measurements of various specific structures, it is appropriate to carry out back analyses together with the analysis of measurement results for existing structures. [19]

Three stage risk analysis procedure was established which is a common approach in large projects. For the preliminary and standard analysis stages soil movements behind the excavation were estimated from the deflected shape of the retaining wall. The relation between wall deflection and surface settlements was established using an empirical method. At the preliminary analysis stage the risk criteria were simply specified. Areas with settlement estimates below 10mm and settlement slope below 1/750 were deemed safe without the need of further analysis. The values selected are in agreement with well-known empirical criteria. [12]

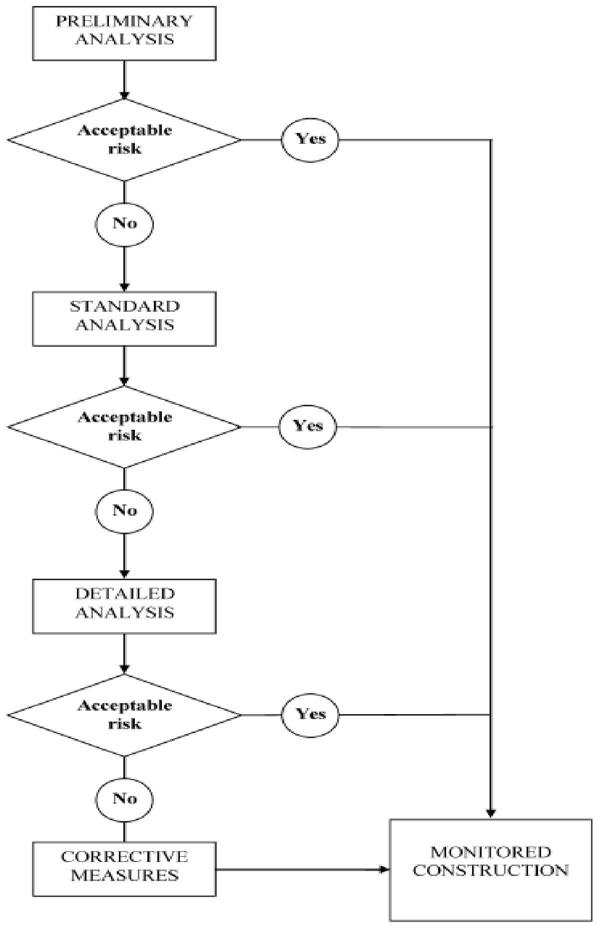


Figure 2.2:- Flow diagram of the third-party risk management strategy [12]

For deep excavation, dilapidation survey of adjacent structures is necessary to prevent unnecessary contractual conflict or even lawsuit. Dilapidation survey also deforms part of the requirements by the local authorities and should be carried out prior to any construction activities at the site. [20]

Normally some of the adjacent structures, especially old buildings, may have already suffered from some cracks prior to construction activities at the site. Therefore, by carrying out dilapidation survey, the developer, consultants, contractor and even the owners of adjacent structures will have a clear picture of the conditions of the structures adjacent to the site. The dilapidation survey report also serves as a reference for any claims by the owner of the adjacent properties on the damages caused by the excavation (if any).

In most of the deep excavation, some movements of the retained ground are commonly expected. The dilapidation survey should cover the area within and beyond the influence zone of the excavation. It should be thorough and with approval of the adjacent owners. The survey should also include the interior of the adjacent structures and settlement of ground especially between suspended and non-suspended structures. If there are cracks on the adjacent structures, the direction of the cracks, the dimension of the cracks like length, width of the cracks should be measured and reported. Photographs should also be taken together with the measuring equipment (measurement tape or ruler) and included in the report [20].

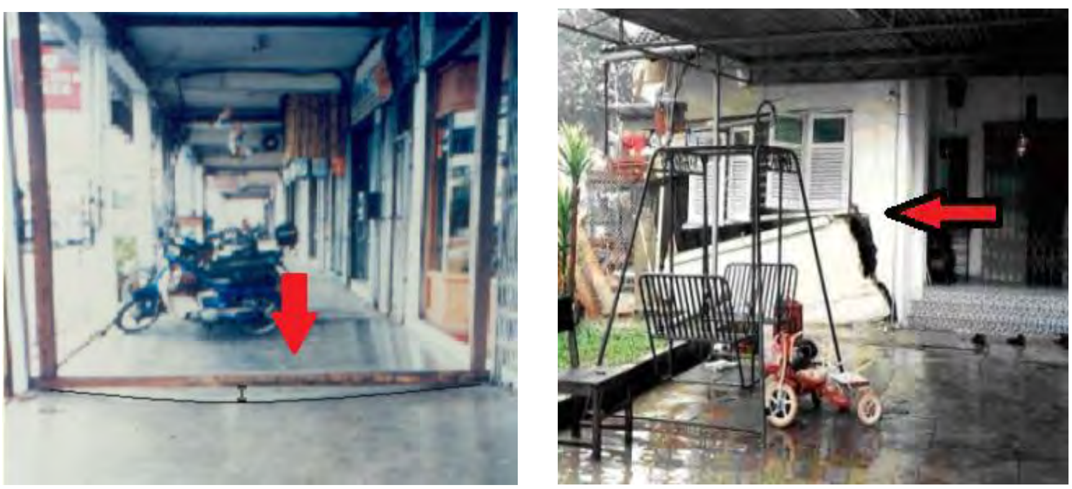


Figure 2.4:- Response of nearby structures to deep excavation [3]

Urban deep excavations in cities quite often cause ground surface settlement which can occur during three construction stages:

(1) **Retaining wall construction**: - as studies show after the completion of the diaphragm walls and before the main excavation, the accumulated deformation was found to be 40-50% of the total deformation after the completion of the main excavation. And the ratio of the maximum settlement induced by the construction of diaphragm walls to the depth of the trench was 0.15% according to in situ monitoring results.

(2) **Ground water pumping**: - most problems encountered in deep excavations have a direct or indirect relationship with ground water. Groundwater induced problems in an excavation may arise from insufficient investigation of groundwater or geological conditions. Thus, it is necessary to perform detailed investigations of groundwater and its influences on soil or structures during excavations. [14]

(3) **Main excavation**: - from observation of the shapes or types of ground surface settlement it can be observed that the soil at the back of a retaining wall moves forward and down as the retaining wall deforms under normal conditions, producing ground settlement. The zone of influence of a settlement should be two or three times that of the excavation depth and in excavation of sandy soils might induce a zone of influence of settlement about twice that of the excavation depth.

In relation to deep excavation work, any associated accidents can easily result in serious damage to adjacent structures or cause human casualties. Ground settlement is especial thought to have the greatest impact on the nearby environment as a result numerical analysis methods and field monitoring are two commonly used tools to predict and assess the ground settlement induced by an excavation. [14]

Numerical analysis methods performed through collection and evaluation of data of surface settlement from underground construction in various locations of the construction site while field monitoring done by accurate and on-time reporting of key measurements of monitoring data obtained from field. Professional engineering knowledge and experience can be used to interpret the monitoring data results to avoid and reduce accidents from occurring. [14]

The other point is to consider risk management, as discussed above defining sources and identifying risk is done in the planning phase then when execution start implementation of the plan is mandatory. Thus in the execution phase risk management should be implemented to improve quantitative risk analyses, which form part of good risk management, improvements are needed to methods that can be used to indicate whether or not and to what extent buildings will be influenced by construction activities. Based on these analyses, relevant measures can be taken in a cost-effective way. [19]

The need for explicit and clear risk management strategies for large infrastructural works is now largely recognized. The risks that have more serious consequences and require more careful management are those inflicted on third parties. The societal tolerance to this kind of risk exposure is quickly decreasing. Third parties at risk might be largely insensible to the eventual medium and large term benefits of the proposed infrastructure. Loss of good will associated to third party damage might jeopardize the success of a project or even its continuation.

Adequate risk management during construction is dependent on accurate and on-time reporting of key measures from the intensive monitoring system. The system can evaluate the probable environmental impacts from the critical monitoring data.

2.1.3. Monitoring & Evaluation

Monitoring and quality control are measurements which should create the possibility to foresee unwanted events and facilitate an incentive to take appropriate measures in order to prevent negative consequences. Measurements for quality control are usually performed only once and are usually not part of a monitoring plan while quality control should be part of monitoring for deep excavation. [6]

In urban areas, deep excavations are surrounded with all sides either by roads, buildings or services. It is very important to have an effective instrumentation and monitoring scheme to make sure that during excavation and construction of the underground structures, the safety of the surrounding properties can be secured. The instrumentation and monitoring scheme also allows the design engineer to validate the design and to identify the need for remedial measures or alterations to the construction sequence before the serviceability of the retaining structures or the surrounding buildings and services are affected. [20]

In general there are four types of objectives for measuring and monitoring identified which proposed as:

1. **Operational/qualitative goals**: Decision making with regard to possible occurrence of risks is improved by measuring failure mechanism development. The progress of construction of the deep excavation is controlled and checks are performed on the assumptions made for the design of the deep excavation. Construction safety of deep excavation and surroundings is also guaranteed. The aim is to reduce uncertainty and gain reliability. In addition, quality control of constructional elements is an operational goal. Examples are load tests on anchors or piles, or torque measurements while installing drilled piles. [4]
2. **Communicative goals:** Deep excavations are often constructed in densely populate areas. Therefore sound understanding between professionals whom participate in the design and construction process is very essential. Also it is very important to get the public's support in order to prevent complaints that can slow down the construction process. Monitoring can be efficiently used to demonstrate the construction process is under control. [4]
3. **Legal goals:** Monitoring can be used to answer questions about liability of building damage. Monitoring can also be a requirement or boundary condition to authorities' permission for deep excavation construction. [4]
4. **Scientific goals:** Monitoring can provide excellent data for scientific research to improve understanding of deep excavation (and soil) behavior.[4]

For monitoring and quality control measurement of deep excavation work, the commonly used instruments are described hereunder:

Table 2.2:- Monitoring Instruments for deep excavation. [20]

Type of Instrument	Description
Inclinometers	Measures the deformation of wall with depth and the access tubes are usually installed in the retaining wall
Piezometers or Standpipe Piezometers	Monitors the change of the ground water level that should be located in lines perpendicular to wall to establish profile and also allows sudden change of pore water pressure
Settlement Markers / Displacement Markers	Installed on the ground in lines perpendicular to measures the settlement of the ground surface profile using levelling
Deep Extensometers	Measures the settlement or heave of the subsoil at different depth and can be installed in the site to monitor the heaving of the subsoil due to excavation.
Load Cells	Installed at the struts or anchors to measure the change of load at each stage of excavation
Tilt meters	Are used to monitor the change in inclination (rotation) of structural element.

Practical monitoring program is essential to the success of the instrumentation and monitoring scheme. For deep excavation, usually the monitoring of all instrument are carried out weekly. In the area where activities like construction of the wall, bulk excavation in front of the wall, drilling of ground anchor etc., the frequency of monitoring for the instruments at the affected area should be increased to daily. If there is any sign of increasing wall movement, strut or ground anchor load above the values designed, the frequency of monitor should be intensified to daily until the causes identified and remedial measures carried out. [20]

In order to ensure the quality of works and safety of the supporting wall for deep excavation, the construction and workmanship shall be closely supervised. The submitting person or his representatives shall supervise the construction ensuring it complies with drawings, specification and use of the approved method. Some of the commonly encountered problems at site that requires close supervision and construction control are:

- During the excavation or drilling of the wall, the construction records should clearly highlight types of soils encountered, rock level (if any), any abnormalities like sudden drop of drilling fluid or water gushing out (artesian). Design engineer has to review the records and confirm the validity of the design assumptions like subsoil types, rock levels and water conditions
- Design engineer should review monitoring records of the instruments and carry back-analysis to validate the design and also to check the performance of the wall.
- During each stage of bulk excavation in front of the wall, the supervising engineer should make sure that the Contractor follows the predetermined design level to prevent over excavation deeper than the design level. Over-excavation increases additional stresses resulting in the increase in wall movement and deformation of the retained soil. Unnecessary over-excavation might even cause catastrophic failure of the wall.
- Surcharging at the retained side of the wall should also be closely monitored. Extra surcharge above the design value increases the soil pressure on the retained soils and may cause increase in wall movement and even failures.
- The drainage system of the excavated platform in front of the wall is very important because bad surface drainage would cause soaking and softening of the soil in front of the wall and reduces the passive resistance supporting the wall.
- If prestressed ground anchors are being used as support for the retaining wall, prestressing and locking off anchors should be carefully carried out at the site. Overstressing of the anchors or locking off the anchors at loads higher than predetermined design values can sometimes cause increase in the anchor load and even to failure. On the other hand, the wall would experience larger movements if the anchors are understressed. Thus prestresssed ground shall be carefully examined & overstressing and understressing of anchor should be avoided to prevent over load and movement of anchor which leads to failure.
- Special care in sealing the anchor holes for temporary ground anchors during construction and after construction is very important to prevent further lowering of the ground water level on the retained ground.

- The drilling technique of ground anchors proposed by the Contractor in the method statement should also be reviewed by the Consultant. For loose soil that is sensitive to loss of materials through the anchor holes, double acting drilling method with temporary casing should be used.
- If internal struts are used, the connections between the waller beam and truts should be in full contact and ensure that the required prestress are applied when specified to reduce wall movement. [20]

On the other hand, vulnerability indexes that have a long tradition for seismic risk analysis are used to building damage assessments. A vulnerability index allows to explicitly account for aspects overlooked or poorly modeled in the methods employed to assess induced building damage. Here, four categories of items were considered in each building to assess its vulnerability to induced movements. These categories were the following:

a. structural aspects (type of vertical bearing elements, type of horizontal linkages, information on foundations & so on)
b. relative location and 3D orientation of the building with respect to the construction site
c. functional and esthetical characteristics and
d. state of repair. [12]

Besides the points described above, risks related problems have to be considered in monitoring for deep excavation work. In the planning phase the sources are identified and in the execution phase the risk analysis were implemented to get improved method of construction then in this phase risk control and contingency plans of action will be presented.

Risk Control

Risk control during the construction stages is insured by periodically reviewing the monitoring report of different variables. The readings are to be compared with the limits set during the design stage. It could be always ensured through the following:

- Incorporating a design with adequate safety factor and reasonable ground movements that could be safely tolerated by the surrounding structures.
- Incorporating an inclusive quality control program during construction.
- Performing a pre-construction dilapidation survey to verify the conditions of the surrounding structures and their safety conditions when subjected to the predicted ground movements.

- Adopting an elaborate monitoring system that suit the risk sources associated with the execution of the deep excavation. [22]

Contingency Plans of Action

Contingency plans are used in the event of emergency response, back-up operations, and disaster recovery for construction projects which carry a large element of risk. The contingency plan shall therefore focus upon ways in which certain events identified through completion of project.

Risk assessments can be militated against using a set of pre-identified procedures. The plan shall be fit-for-purpose and undergo the following key tests prior to its release:

- Is the plan achievable in reality, should this be required?
- Are the trigger mechanisms for actual activation of the plan clear and realistic?
- Does the plan address anticipated situations in a timely, affordable, effective, consistent manner? [22]

Thus the goal of monitoring is to provide useful scientific information about the status and trends of various factors affecting the environmental impact of a project, particularly for urban deep excavations.[14]

2.3. Challenges in Deep Excavation

Numerous engineering problems are likely to be encountered as construction works are going deeper and deeper down into the ground. Engineers and builders have to face a lot of problems such as the existence of complicated sub-soil, overcoming of tremendous soil pressure, the provision of complicated temporary support works and working in congested underground or sensitive nearby environment. [17]

Problems and failure costs related to underground construction (e.g. for underground parking facilities, basements, infrastructure) are increasingly acknowledged, since it has become clear that they have a large influence on the image of the sector and the results in terms of money 5-10% loss of effectiveness due to failure costs compared to 2-3% net profit. [4]

The construction of deep excavation is technically challenging task which requires serious attention and follow up to avoid any associated accidents which can easily result in serious damage to adjacent structures or cause human casualties. Mostly these difficulties are ignored and left carelessly but lately could develop to failures.

Here some cases of the failures observed in deep excavation are presented; primarily the possible technical issues are described below:

a) Inadequate instability analysis of an open cut excavation can lead to a slope failure which in turn causing driven piles that had been put into place were subjected to large lateral force that lead to the piles. The consequence of such a failure in a building foundation, new piles have to be reconstructed. [9]

Figure 2.5:- Failure of Open cut Excavation that Lead to Driven Pile Foundation Failures- North Jakarta-2005 [9]

b) Insufficient toe penetration of steel sheet piles, would lead to excessive movement of the sheet pile would lead to excessive movement of the sheet piles toe, which often lead to kick in failure. This kick in failure would then lead to large and often sudden sagging of the ground behind the wall. If this event were to take place near adjacent buildings and utilities, the buildings and utilities would have had collapse. [9]

Figure 2.6:- Kick in Failure of Sheet Pile-Surabaya-2007

c) The earth pressure induced by soft clay was often wrongly calculated, as a result, a cantilever sheet piles wall system was in total failure causing the seven to collapse and traffics were severely interrupted. Further lateral movement of the soft soils was tried to be stopped by installing 60cm diameter soldier pipe piles. The pipes were also casted with concrete, but it was not successful. The pipes were eventually slanted to almost 30 degrees. One must understood that once the soil movement exceeds their yield stresses, it will be very difficult to stop further movement. [9]

Figure 2.7:- Failure of Sheet Pile Walls; Further Soil Movement was tried to be stopped by Soldier Pipe Failed-West Jakarta 1995. [9]

The above cases shows the failure of retaining wall for very soft to soft gray to black clay, but for strong, medium to stiff clays the failure of retaining walls with inadequate provision of soldier piles, the capping beam and the soldier piles moved excessively and broken which is shown below; and due to careless open cut excavation collapse of a Thirteen stories building in China. Similar problem were observed in Indonesia whereas nine story building tilted severely and it was totally destroyed. A serious incident of excavation failure had caused the loss of four lives in Singapore, the collapse of pedestrian bridge and the total cut off of a major highway. [9]

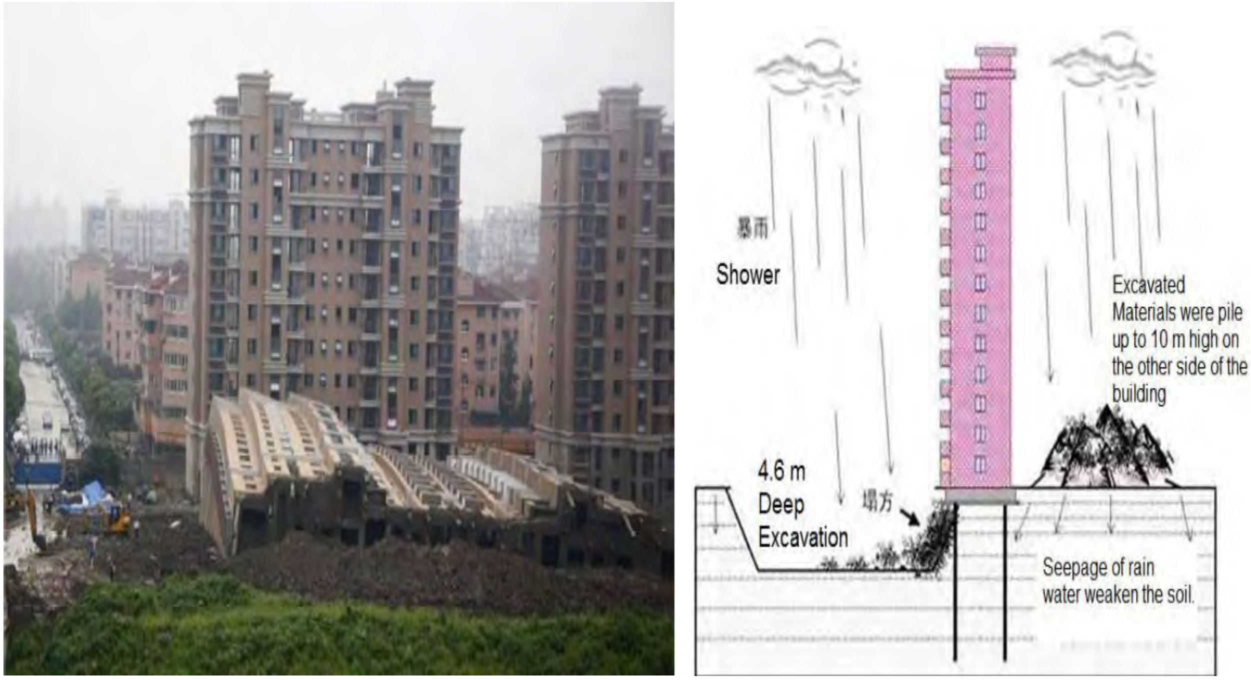


Figure 2.8:- Ignorance of Open cut excavation led to a building collapse – China [9]

Figure 2.9:- Mass Rapid Transit cut and cover excavation failure – Singapore [9]

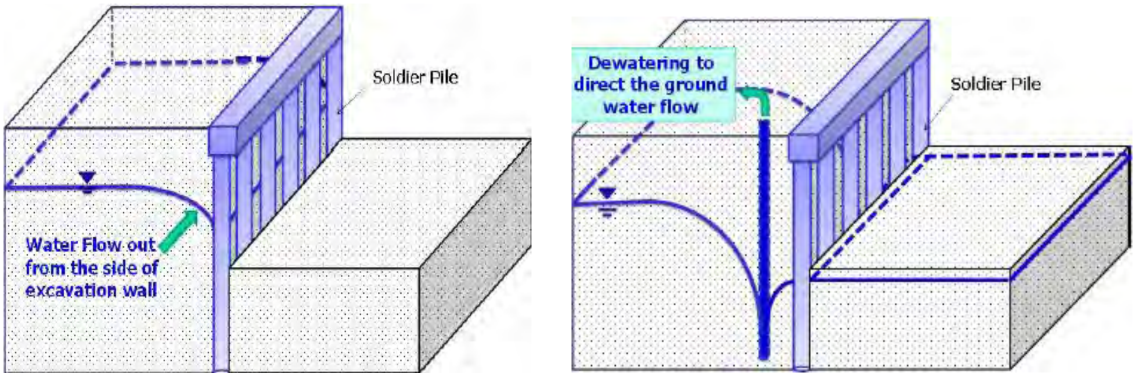
There are also technical issues that can lead to failures which can often be ignored or forgotten or wrongly calculated in the design stage and in the execution phase; some of them are:

a) Water pressures

Fluctuation of ground water tables must be investigated. In area where rain intensity is high, the difference within the rainy and dry season can be of several meters. When excavation is executed near a river or sea shore, the influence of high and low tides to the ground water table also need to be investigated. Failure in estimating the ground water tables shall lead to the wrong calculation of water pressures acting on the retaining walls, and it can contribute to excessive movement of the retaining wall. In an adverse condition may also cause failure. Observation of ground water table through soil investigation boreholes only is inadequate. The proper measures should be performed by installing observation wells and piezometers, best installed in every significant layer of soil. The measurement should span over the rainy and dry season. By employing this method, the correct water table during the dry and rainy season can be identified. The existence of artesian water pressure, if any, can also be identified. [9]

b) Seepage force

Seepage of ground water toward the excavated area is often forgotten in analyzing the stability of earth retaining structure. The mode of the seepage depends on whether water can pass through the retaining wall or not. For open cut excavation and retaining wall systems where water can seep or flow through the wall. Therefore, it is very important to prevent the ground water to flow out from the slope of the open cut excavations or through the walls of the retaining wall system. For that it is advisable to install dewatering wells at the perimeter of the excavation area. For an excavation with impervious retaining walls like diaphragm walls or secants piles, where the toe of the walls is located in a permeable soil layer, then it will not act as a water cut-off system. Means water can seep from outside into the excavation area through the permeable soil layer below the walls toe, which creates seepage force that increases the effective overburden pressure in the active side of the walls and on the other side reduces the effective stress in the passive side of the walls. This means the seepage force increases the lateral pressure to the walls and decreases the passive pressure. A large seepage force may significantly reduce the effective overburden pressure and subsequently will induce piping and boiling. This effect of seepage force is often forgotten by inexperience design engineers and contractors. If the retaining wall is embedded into an impermeable layer, there will be unbalance water pressure within the active and passive sides. When the base of an excavation is impermeable, say by jet grouting a layer at the base of the excavation, the base of the excavation is then subjected to an uplifting force. Therefore, to withstand this uplift force, thickness of the base has to be calculated. Ignorance in calculating this uplifting force can cause failure. [9]



Ground water seepage through solider piles

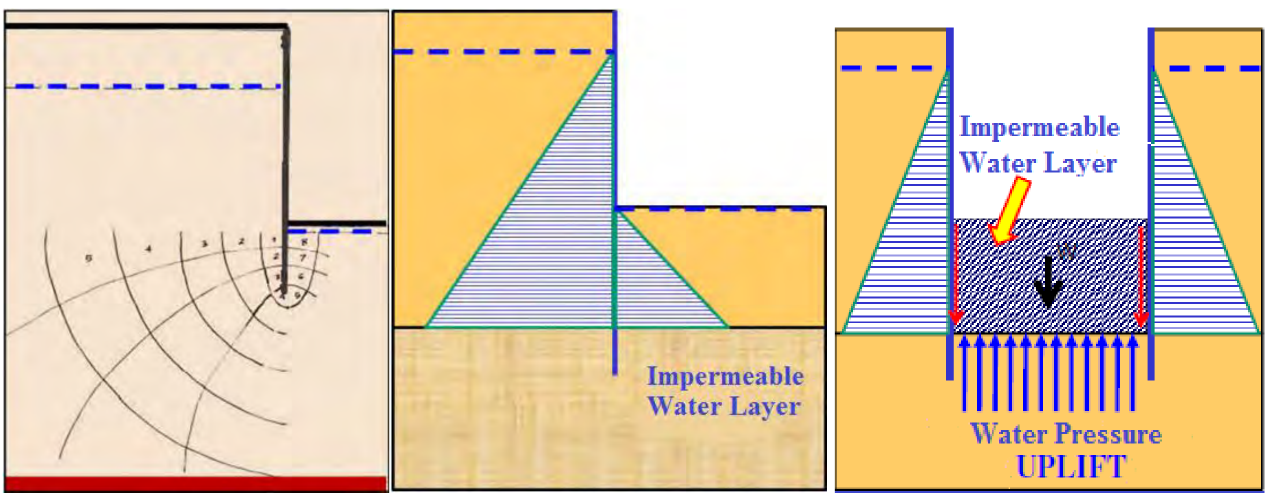


Figure 2.10:- Ground water seepage through impervious wall; Unbalance water pressure and Impermeable layer at base [9]

c) Artesian water pressure

The existence of artesian water pressure can greatly affects the stability of an excavation. The weight of the soil from the excavation level to the top of the aquifer layer and the friction of the soil wall system should be able to withstand the artesian pressure; otherwise the base of the excavation shall fail. This type of failure is known as bursting or boiling. In a smaller scale, the seepage of the artesian water reduces the passive resistance of the soil. Undetected artesian water pressure beneath an excavation may lead to unsafe excavation. [9]

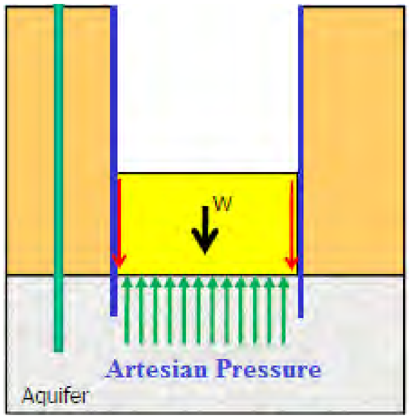


Figure 2.11:- Artesian water pressure [9]

d) Squeezing/soil flow and heaving

When soldier piles system is used as retaining structures for soft soils, soil squeezing or soil flow through the gaps within the soldier piles may the place. This phenomenon may affect the stability of the structures/facilities adjacent to the excavation area. Therefore, it should be noted that the gaps within the soldier piles must be close enough to ensure the formation of arching (arching effect) where the soft soils couldn't penetrate or squeeze out of the gaps.

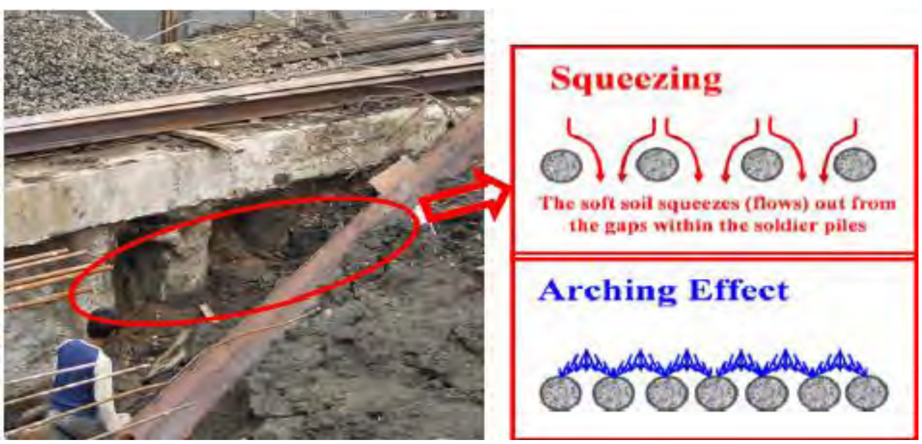


Figure 2.12:- Squeezing or Flow of Soft Soil through the Gaps within Soldier piles. [9]

e) Heaving

For braced excavation system, it is quite common that the design engineer forget to take into account the heaving mode of failure. This mode of failure can take place due to the weight of the soil columns, of 0.7 excavation width, at the sides of the excavation pushing inward from the bottom of the excavated area. If the bearing capacity of the soil beneath the excavation area is unable to withstand the soil column weight, then heaving failure can take place. [9]

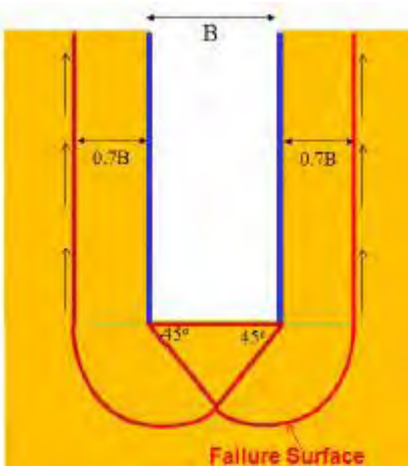


Figure 2.13:- Heaving Mode of Failure [9]

In the execution of deep excavation different challenges observe due to a number of causes, such that some of the cases will be reviewed hereunder:

In Netherland 50 deep excavations were studied while in 61% of the cases the wall of the deep excavation caused damage. In a quarter of these cases, the installation of the wall played a major role and in another quarter excessive deformation occurred due to problems with the stiffness (mostly cantilever types) or strength of the wall. The function of the deep excavation wall is to retain ground and ground water, its stiffness and strength must keep the wall deformation within acceptable limits. In half of the cases the water retaining function was compromised, so that leakage from a steel sheet pile wall, secant pile wall, diaphragm wall or jet grouted wall took place. Damage to the adjacent buildings is mainly caused by inadequate performance of the wall (including the anchoring system) or by damage during the installation of the wall. [7]

When failure occurs in deep excavation an important question usually is whether the problem is caused by the design or the execution of the project. In most of the cases where the study addresses, the design played a crucial role in the origin of the failures. The designer of the wall (which can either be an engineering firm or a contractor in an integrated contract) often disregards the installation effects of retaining walls and foundations. A lot of effort is put into the design of the wall stiffness and related assessment of possible damage to properties, but the installation and the associated deformations are often excluded. The reluctance of designers to take issues of constructability into account is often due to perceived liability issues. [7]

Sometimes the deformations caused by the excavation were not larger than foreseen, but an incorrect assumption was made about the type, dimensions or quality of the foundation of the adjacent buildings. This was the major cause of failure in 10% of the total number of projects.

Occasionally the naturally available sealing layer in the soil was absent locally, which had not been identified before construction due to insufficient ground investigations.

In urban areas, it is not always possible to perform ground investigations as buildings to be relocated in a later stage are still present. In such a case, it is known in advance that there is an increased risk that the soil profile might deviate locally. In several cases, the excavation was deeper than designed for, usually for local elevator pits. Sometimes even the vertical equilibrium, including all the 3D effects was not sufficient to prevent uplift. Artificial seals such as injection layers are commonly known to be sensitive to construction practice and might not be water proof, but merely water resistant to a certain degree. If this is taken into account in the design, this need not be a problem. [7]

Foundation piles in or adjacent to deep excavations may be damaged during the excavation. This can be caused by horizontal deformation, especially in very soft soil or by swelling. Damage due to the latter can generally be prevented by adequate pile reinforcement. Other failures are related to anchored concrete floors. Many floors are anchored with micro piles, which are very sensitive to installation procedures. Relatively few accidents have occurred, mainly due to the increasing awareness of the sensitivity and the subsequent implementation of test programs and pile tests.

As per the study, it had been concluded that in 77% of the cases failure could have been avoided if proper risk management had been applied during the preparation of the project. Risk management also may have identified the lack of knowledge of the staff working on the project. [7]
During construction of such projects, problem such as settlement of foundation of neighboring buildings and collapse of earth retaining wall sometimes occurs. The most frequent problem concern dewatering, temporary earth retaining structures and workmanship. While excessive water pressure often triggers leakage of water from ruptured part of foundation base leading to base settlement and deposition muck. [8]

On the other hand, when we come to Indian practice there are four major points where problems observed in relation to foundation construction of deep excavation projects which are discussed below.

a. Excessive Water Pressure

The failure of foundation occurs due to high uplift pressure by water. This force causes uneven settlement of foundation. This force during construction phase causes complication for laying of foundation concrete in such a way that it raptures the base of foundation over which steel has to be placed. The uplift pressure of water can cause seepage of water from ruptured base leading to creation of muck which makes conditions unworkable and also leads to formation of small ponds where soil has settled. [8]

Thus, investigation revealed improper or less efficient dewatering system which leads to such complications and if not controlled all these factors have potential to cause catastrophe and delay the project to a large extent.

b. Improper Dewatering Procedures

Inadequate dewatering procedure for deep foundation construction project cause many undesirable consequences which include settlement of existing buildings, cracks in walls and slabs of existing nearby buildings and improper working conditions, collapsing of soil from earth brims /shores. Particularly, if improper dewatering procedures are followed improper working conditions and collapsing of soil from earth brims are far most common problems. [8]

The most frequent problem concern dewatering, temporary earth retaining structures and workmanship; while excessive water pressure often triggers leakage of water from ruptured part of foundation base leading to base settlement and deposition muck. When dewatering is performed without adequate water-table monitoring procedures, settlement of the soil surrounding the excavated area can occur.

c. Poor Workmanship Steel Placement and Binding

As, for any structure to gain strength, the reinforcing steel bars need to be placed with great precision, proper cover and avoiding contact with water, prior to concreting is important. Often the steel gets exposed to water in these kinds of construction projects prior to concreting.

d. Improper Soil Nailing and Shotcreting

In one project, soil nails were driven and left as shotcreting was delayed. Because of delayed shotcrete the soil of earth brim started to erode and fall in excavated area. It also added to formation of muck in excavated area. [8]

In another way one of the major issues with respect to deep excavation management is the bidding system, where the "lowest bidder wins" system with the intention is to achieve cost efficiency. However, it also carries the negative side effect that is the tender participants will try to cut cost here and there, very often, by sacrificing quality and safety. The participants that lost in one tender would bid lower in the next tender, then the ones lost in this tender will also bid lower in subsequent tenders and the trend goes on until it reaches unhealthy state where the consultants, contractors and subcontractors don't have enough profit margins. The effects of this are:

- Consultants can't pay qualified engineer in a reasonable manner, they don't have enough budget to enhance the knowledge of their engineers; very often they even don't have money to upgrade themselves. Unable to attend good seminar and courses, unable to by licensed software, not to say to develop research and development department. Low and inadequate income make good engineers seek for other professions. The effect as example the soil investigation report and the design quality will be lower and lower.
- The main contractors shall press subcontractor pricing, then who will the subcontractor press? The clear facts are everyone will cut cost here and there. The first stage is trying to cut construction temporary supporting elements (temporary work), for examples: omit the capping beam that tie diaphragm walls panels/soldier piles into one system, omit some waller beams in a strutting or ground anchoring system, reducing the number of struts, cut cost on the dewatering system. When cutting is successful in one project, the contractors are getting daring from one project to another. They forgot that the soil condition varies from one place to another. This kind of cost cutting on temporary work which is often take place in the execution of deep excavation, can lead to fatal failure. One of the causes of the failure on the cut and cover Mass Rapid Transit excavation of Singapore mentioned above was improper strutting system.
- The next effect of unreasonably low cost is the consultants/ contractors try to cut overhead. They don't have budget to hire qualified engineers, especially good geotechnical engineers. The consequence is they are unable to see the danger that may take place. Despite the fact that the engineers very often have to work overtime with no compensation at all, the salaries of the engineer are inadequate. While the cost of living increases year by year, the engineers' salary hardly moves up, sometime they even get reduced salary under the reason of economic crisis. Compared to their peers in the financial world their salary are way too low, therefore, the capable engineers start to seek for another professions that give much better compensation. Of course the scarcity of good and qualified engineers leads to lower quality of construction work.
- The saddest thing of all is the engineers that pressure engineers, just merely to follow the instruction of the owners. The engineers that act as a quantity surveyor often carry out the "price negotiation" with very shallow basis. They collected lowest pricing of every items from every contractors, the

quantity surveyor doesn't (and doesn't want to) understand geotechnical work. They couldn't see the potential problems of low costs and they don't want to understand what they are negotiating at. Their attitude shows that they aren't qualified to be named quantity surveyor. Ones don't need an engineer for doing that way of negotiation. Good quantity surveyor must understand what he is negotiating at, how to carry out the construction work, want to understand and want to seek and to survey for proper pricing of every item he is negotiating at. He must give feedbacks to the owner on the proper price level and not only pressing the pricing of the consultants/ contractors/ subcontractors. [9]

2.4. Remedial measures for Deep Excavation

In deep excavation, quality and safety of the construction are key factors so that suitable construction method, supervision and monitoring system must be adopted. The design assumption must be clearly stated in the design report and it has to be explained to the contractor. The contractor must pay attention to all the design assumptions, if there is any discrepancies in the field, the contractor must report and carry out coordination with the designer. So that problems and unwanted effects can be minimized and eliminated.

Moreover, strict quality control measures should start early during the prequalification of the foundation contractors. Qualified foundation contractors should have adequate knowledge about the soil conditions of the excavated area.

When ground water exists that results water pressure proper, dewatering is necessary. As dewatering is the process to remove the over saturated water in ground and keep the subsoil within a non-saturated condition. When it is performed without adequate water-table monitoring procedures, settlement of the soil surrounding the excavated area can occur. It is recommended that planning of a dewatering system should refer to the original design data, boring logs, and the instrument system data. Due to non-homogeneous and non-isotropic soil properties, monitoring and, if necessary, modifying construction operations before each stage of excavation should be performed. Survey and evaluation of the neighboring structures and facilities before, during, and after the excavation are extremely important. If observations of a neighboring structure or facility indicate an inadequate foundation, underpinning or grouting of the existing foundation also should be performed. [8]

The other common problem in the construction of deep foundation is poor reinforcing steel placement. Such placement requires accuracy, particularly when the foundation is deep. Often the steel gets exposed to water in these kind of construction projects prior to concreting. The effect of exposure of steel can be diminished by coating steel with cement slurry coating. This will make a protective layer around reinforcement bars and will diminish rusting of reinforcement bars. [8]

Whereas, the problem of soil erosion from earth brim is concerned, it can be prevented by carefully and properly monitoring soil nailing and shotcreting process. One thing should be taken care of that after the nails are driven into soil, after that they should be locked with the help of mesh of desirable size and a bearing plate mostly of size ranging from150 sq. m to 250 sq. m, followed by shotcreting. Iron nails should not be left exposed for a longer period of time and stricter quality control measures should be adopted. [8]

In the presence of utility lines in the construction line the contractor or professionals assigned on the site required to protect their safety therefore, before starting work its mandatory to determine the approximate location of utility installations like sewer, telephone, fuel, electric, and water lines or other underground installations; Contact the utility companies or owners involved to Inform and ask the utility companies or owners to find the exact location of underground installations. Else if the excavation work exposes underground installations, the contractor required to protect, properly support or remove them. [1]

Besides, to prevent or minimize the risk of failures and problems in deep excavation the succeeding procedures are forwarded as remedial measure;

- Appoint a capable geotechnical engineer or expert to assess the problem at hand.
- Carry out an adequate, proper and systematical soil investigation as pointed out by the geotechnical engineer
- Analyze, interpret and derive the geotechnical design parameters based on the available soil data. Whenever necessary carry out additional soil investigation. In a large and/or important construction, geological and seismicity of the area need to be investigated as well.
- Asses and understand the type of construction to be built and also the possible loading imposed to foundation/ground.
- Carry out the short term and long term stability and the possible deformation of the planned structure.
- While building the structures, install instrumentation systems, examples: piezometer, inclinometer, pressure cells, etc. Carry out proper and systematical monitoring based on the installed instrumentation. Interpret the data properly where independent institution is highly recommended for this aspect.

- Compared the monitoring measurement taken in the above step with the design (prediction) made prior to construction. Carry outback analysis and do the necessary correction. Admit the error when one, as an engineer, made an error in our prediction or calculation and immediately seek for remedies. If necessary ask for help from a more experience engineer.
- Whenever necessary carry out quality control testing for examples carryout sonic logging test to check the soundness of piles, perform static loading test to check the capacity of piles, etc.
- In handling a new type of problem which is complex and difficult, it is better to seek an advice from fellow capable engineers.
- Professionals engaged in the specific work should be honest to their capability and should never pretend to be clever on everything. Even in the field of geotechnical engineering, the geotechnical expert will not master every aspect of geotechnical engineering and geotechnical construction so that this should be considered in mind.[9]

Distribution of earth pressure influences stability, stress, and deformation analysis of the deep excavation. For problems of excavation, considering that the active earth pressure is usually the main force leading to the failure of the excavation supporting systems. The passive earth pressure is usually the force resisting the failure. The pressure distribution shall depend on the nature of backfill.

Stability of excavation is the major design criterion in order to avoid collapse of excavations. Stability analysis involves the distribution of earth pressures such that provision of support system such as shoring, bracing or underpinning to ensure that adjacent structures. The professional should be responsible for maintaining materials and equipment used for protective systems. Defective and damaged materials and equipment can cause failure of a protective system and other excavation hazards. Thus a registered professional engineer should evaluate and approves these materials for use. [1]

Besides the remedial measures discussed above the possible focus area to eliminate the problems and challenges is summarized with pie chart in Figure 14 below. The major areas that require emphasis are education in design review the failure cases could have been avoided with a proper training and education of the geotechnical staff and risk analysis that is proper risk management or implement improved method. Then performing new researches that can address those challenges and failures comes in the third place. Site investigation is also the other major issue which requires high focus and the base to solve most problems related to technical subjects; lack of information regarding the adjacent foundations and related data can however be managed by carefully analyzing all possible consequences. This may be achieved by identifying possible events, assessing the importance of the event and defining the necessary countermeasures (and related costs) that eventually should be taken. The same applies for the lack of ground information. In many cases, it is impossible to do proper soil investigation because existing buildings are still present on the jobsite. Then just at the start of the project the existing buildings are demolished and borings are performed often leading to surprises and additional costs. In addition, these surprises can be avoided with a proper risk assessment during the design process of the project. Monitoring is the last but not the least subject which requires attention and implementation.

Therefore, it can be concluded that in 77% of the cases failure could have been avoided if proper risk management had been applied during the preparation of the project. Risk management also may have identified the lack of knowledge of the staff working on the project. Therefore, the challenge for the education of geotechnical engineering is to not only teach a good theoretical base but also to convince the students to apply risk management during the entire design process. Especially the young geotechnical engineers without experience should be familiar with a risk-based approach for the field of geotechnical engineering in which practice and experience play a major role. [7]

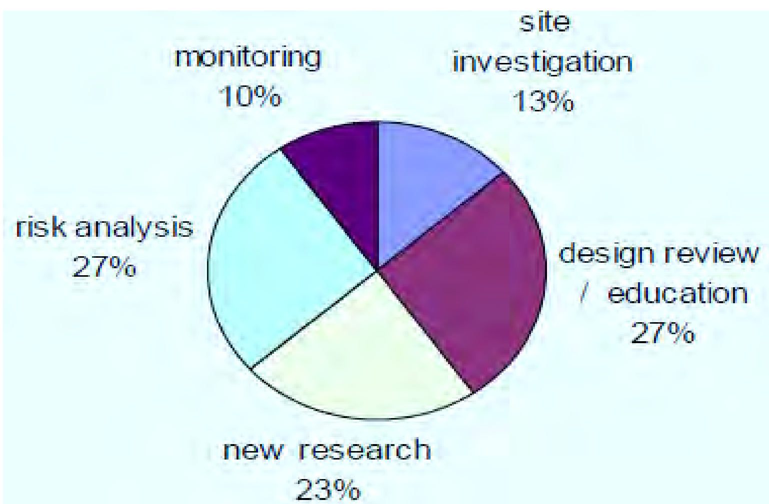


Figure 2.14:- Focus of possible measures to improve performance [7]

In general, for deep excavation execution prediction of deep excavation performance involving both stability and limitation of deformation is very important. While stability tells that the excavated wall isn't endanger of collapse and whose base doesn't heave uncontrollably and although the Limit of ground deformations let's to know the adjacent buildings, streets and utilities around excavations can be damaged or not.

3. METHODOLOGY

In this part, the methodology adopted for this research will be discussed. The research approach and the demarcations are coupled with data collection methods and how the analysis was made.

3.1. Approach and Research Type

There are two types of researches i.e. qualitative and quantitative researches where the division bases on the way in which the research objectives can be questioned. A qualitative research is a “subjective” assessment of a problem and takes the form of an opinion, view, perception or attitude towards objects (that are referred to as an attribute, variable, factor or question). Quantitative research, on the other hand, is an objective measurement of the problem that investigates facts and tries to establish relationships using statistical tools. This research is basically of a mixed research type where both qualitative and quantitative methods are employed. [25].

The research strategy adopted can be categorized as exploratory and descriptive type. It is exploratory because the research was initiated to identify practical problems and attempts to find present challenge, factors of challenges and remedial measures in execution of deep excavation. It is also descriptive because it tries to describe the overall practice of execution management in A.A. construction projects.

In this study, interviews, structured questionnaire and site visits were used in the gathering of data. The interviews were adapted to collect detailed information about respondent’s experiences and impressions about Construction of deep excavation in urban and congested area. It was also used to collect preliminary information to help in structuring questionnaires.

The questionnaire survey was also adapted to get feedback on views of respondents towards deep excavation work in Addis Ababa construction industry. The site visits involved observations where the researcher sought to find out how is deep excavation deployed on site with the execution management and quality assurance practice. The researcher spent time seven (7) months on seven (7) building construction sites, one (1) from road & one (1) railway by observing the execution of deep excavation work.

The questionnaire survey focuses on the three main procedures and challenges with their remedial measures to be followed in the construction of deep excavation. Photos were taken during the site visit to support the data collection.

3.2. Data source

The research data was collected based on the stepping points found in the literature review on the execution management of deep excavation. The sample were drawn from Clients, Addis Ababa City Road Authority and Addis Ababa Light Railway Transit (AALRT) for underpass road and railway projects respectively. For building projects in A.A. under construction clients, consultants and contractors involved in deep excavation and skilled professionals in related construction work were taken. Those elements were selected without limitation except their professional skill and experience in the specific work.

3.3. Data collection

The data collection approach adopted for conducting this research includes both primary and secondary sources. Questionnaire, interview, and observation provide the primary data for this study while the secondary data sources include journals, internet sources, as well as reviewing related archived documents on execution of deep excavation. These different methods of data collection have been used in order that the data or information obtained from one can be supplemented by the others whereby the collected data will give multiple evidences.

3.3.1. Questionnaire

Questionnaire provides firsthand information for the subject matter of a research as it is focused on issues which further serves as a survey to understand the main concerns and attitudes of respondents towards the problems. In this study, questionnaire was administered to some randomly selected stakeholders in the construction of deep excavation. [25]

The study has used the data sources to produce the following basic documents: respondents' documents and site observation. The respondents' documents were collected using questionnaires from clients (project owners), contractors and consultants. The two basic types of survey questions which are: questionnaire have been used in this research.

The questionnaire have been categorized into two; open-ended and closed-ended groups in which the first group contains four part where part I raises general questions related to the planning of deep excavation work that involves the design, construction planning and health & safety planning. Part II contains questions related to execution practices on construction and health & safety implementation. In Part III the respondents were asked how they perceive the practice of monitoring and evaluation in deep excavation work. And Part IV deals with questions related to technical and non-technical challenges. Finally, in the second group respondents were asked to give their experience of challenges with the remedial practices in execution management other than mentioned in the first group.

3.3.2. Interview

Interview is one of the primary data collection methods which is flexible and adaptive way of investigating underlying motives of a subject in a way that self-administered questionnaires cannot [26].

The interview undertaken for this thesis was based on semi- structured style. This type of interview has a predetermined set of questions (generalized form of questionnaire) with a flexible order depending on what the interviewer perceives the subject matter by looking at the respondent capability and exposure or experience. The interview for this thesis was done with eleven reputed professionals of the sector, who have strong expertise with regard to the deep excavation work in focus. From these interviewed professionals, two from client, four from consultants and the rest five were from contractors.

3.3.3. Observation

Observation to some selected projects were used in this research to support or supplement responses and arguments found through questionnaire and interview. Nine undergoing construction projects who engaged in deep excavation work were observed to find out how deep excavation is implemented and managed in local construction projects. Photographs were taken as supportive & descriptive data.

3.3.4. Secondary Data Sources

The secondary data were obtained from relevant books, journals, magazines and research papers which have been used to perceive the practice of deep excavation management. These secondary sources provide a general understanding of the subject area by presenting a wide range of ideas in the field which help to supplement other specific information obtained from the primary data sources.

The data collection was the most tiresome part in this research. The major difficulty was the respondents' unwillingness to respond and reluctance to react as per their promised schedule that made the research stressful for the period of data collection.

The responses for the structured part of the questionnaire are organized based on Likert's-scale of five ordinal measures of agreement towards each statement (from 0 to 4) as shown below, which are Likert scale's intervention that is attributed by Dr. Rensis Likert (1932), who described the technique for measurement of attitudes in scientific way. The reasons for adopting this simple scale are:

- to provide simplicity for the respondent to answer, and
- to make evaluation of collected data easier

Likert's-scale is important to know respondents' feelings or attitudes about something. The respondents must indicate how closely their feelings match with the question or statement on a rating scale. [26, 27]

After identifying the factors that have impact on the management of execution of deep excavation, respondents were asked about the impacts of each factors of deep excavation based on the following choices.

0- No significance

1- Minor significance

2- Average significance

3- High significance

4- Extreme significance

3.4. Data Analysis

Since Likert type of questionnaire used, the analysis have been performed by identifying the Relative Importance Index (RII) method. The relative importance index method is used to determine the relative effect of the factors affecting the performance of the construction of deep excavation. The clients, consultants and contractors experience on the effects of the factors are used as an input in the formula. The relative importance index is computed as follows. [28, 29]

Weighted average

$$\mathbf{RII} = \frac{\sum W}{A \times N}$$

Where:

W is the weight given to each factor by the respondents and ranges from 0 to 4

A = the highest weight = 4

N = the total number of respondents

N	n1	n2	n3	n4	n5
5(0-4)	**ES**	**VS**	**MS**	**SS**	**NS**

$$\mathbf{RII} = \frac{4n1+3n2+2n1+1n4+0n5}{4N}$$

Subsequently, the statistical tools for data analysis and the background, statistical results obtained from the data are discussed in chapter four.

4. ANALYSIS OF FINDINGS AND DISCUSSION

4.1. Introduction

This chapter deals with the analysis of gathered data and presents discussion from the result of analysis on the major issues by combining with literature review. The data collection was carried out through interview, questionnaire and observation in randomly selected construction projects. Also for the purpose of this research, site visit of undergoing projects was accomplished.

The aim of this research is to assess the practice in planning, quality assurance services and execution management, identify the problems and deals with the gaps that need to be improved in planning, quality assurance and execution of deep excavation.

The procedure applied to analyze the result of the questionnaire is by forming the Relative Important Index (RII) for the factors of challenges and unwanted effects. The question presents opportunities of responses as Extreme Significant (ES), Very Significant (VS), Moderately Significant (MS), Slightly Significant (SS) and Not Significant (NS), to identify the factors as the frequency of occurrence of the variable and the percentage of respondents' answer were ranked for the analysis purpose. Through this ranking it was possible to identify the major causes for the challenges and unwanted effects that have impact in the management of deep excavation construction.

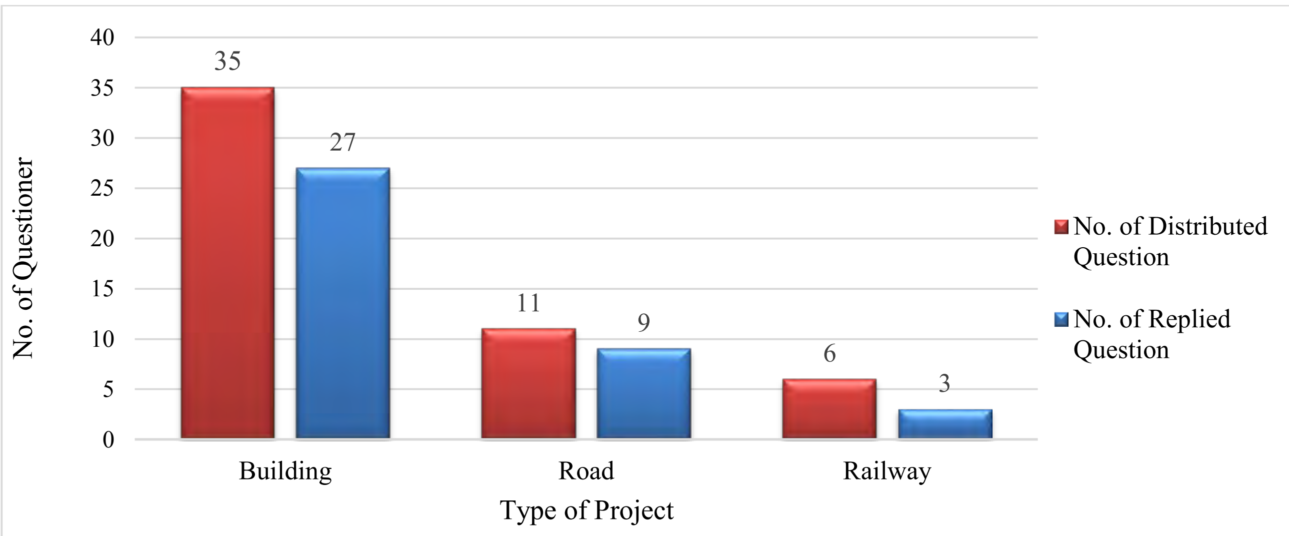
4.2. Responses to Survey

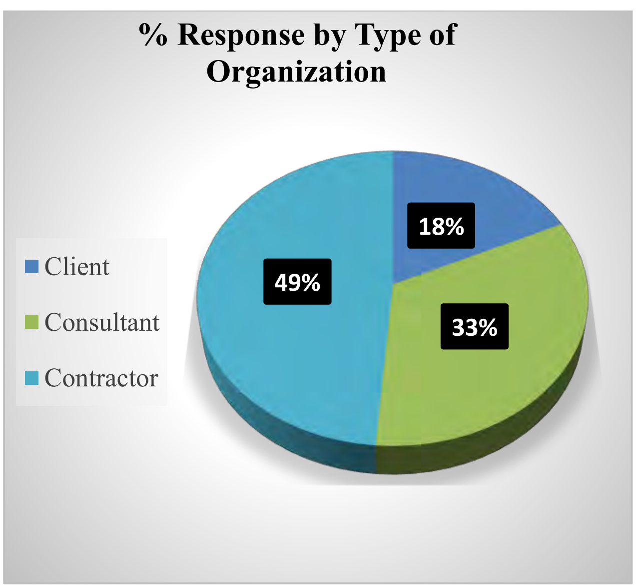
This study has focused on directly participating key professionals of the construction stakeholders who were engaged in the construction of deep excavation for high rise building, under pass road and railway projects. For key professionals of randomly selected projects detailed structured questionnaire was distributed. To make the analysis more comprehensive the questionnaire were dispersed to contractors, consultants and clients of different projects; a total of 52 questionnaires were distributed out of which 39 (75%) were filled and returned in building, road and railway projects. Table 4.1 and figure 4.1 present the illustration of response rate in terms of organization and project type. In addition, ten reputed professionals of the sector (two from client, four from consultants and five from contractors), who have strong expertise with regard to the deep excavation work in focus, have been interviewed and their responses have been supplemented with the questionnaire survey.

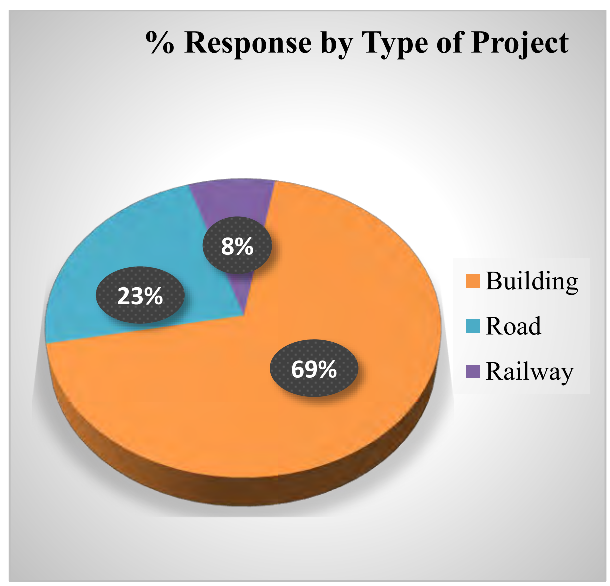
Table 4.1:- Frequency and percent type of organization

Type of Organization	Distribution in No.	Response in No.	Response Rate in %
Client	8	7	87.5
Consultant	16	13	81.25
Contractor	28	19	67.86
Total	52	39	75

Figure 4.1:- Frequency and percent of response by type of project







As we can see from the table 4.1 and figure 4.1 the response rate of contractors with respect to the distributed amount of questionnaire is better than other parties.

With the category of projects railway has the least response as their participation was very much less due to unwillingness of stakeholders.

On the other hand, nine undergoing construction projects which were engaged in deep excavation work were observed in detail though the findings from the observation is accompanied in the analysis of data found from questionnaire and interviews.

4.3. Deep Excavation Works Execution Management Practices

In conducting this research, the primary concern was to identify how deep excavation implemented in Addis Ababa construction projects. Engaging deep excavation widely, performing geotechnical investigation and testing of construction materials are appreciative practice. Poor experiences in safety & health management, less protection of the surrounding environment, accident, and failures found as a result of instability of excavation and less implementation of quality assurance and construction work methodologies are deemed as bad experiences in A.A.

As deep excavation requires careful planning to attain the intended quality, effective and efficient utilization of resources with safe working condition; different mechanisms are applied or adopted but faces many challenges as it is performed in urban and congested area. In the local construction practice especially in A.A. deploying deep excavation has its own limitation and challenges. To determine the factors that influence the execution management and the causes that cultivate problems and unwanted effects, the hypothesis factors were developed in closed question where the rest practice with the remedial measures was incorporated with open questioners. Thus the outcomes of the questionnaire discussed further below.

Hereunder the most common practices that occur frequently in the local practice were construction of deep excavation are presented by pointing out the highly ranked items that have greater values of Relative Important Index (RII). Whereas the whole analysis result of the questioners is presented in the appendix C.

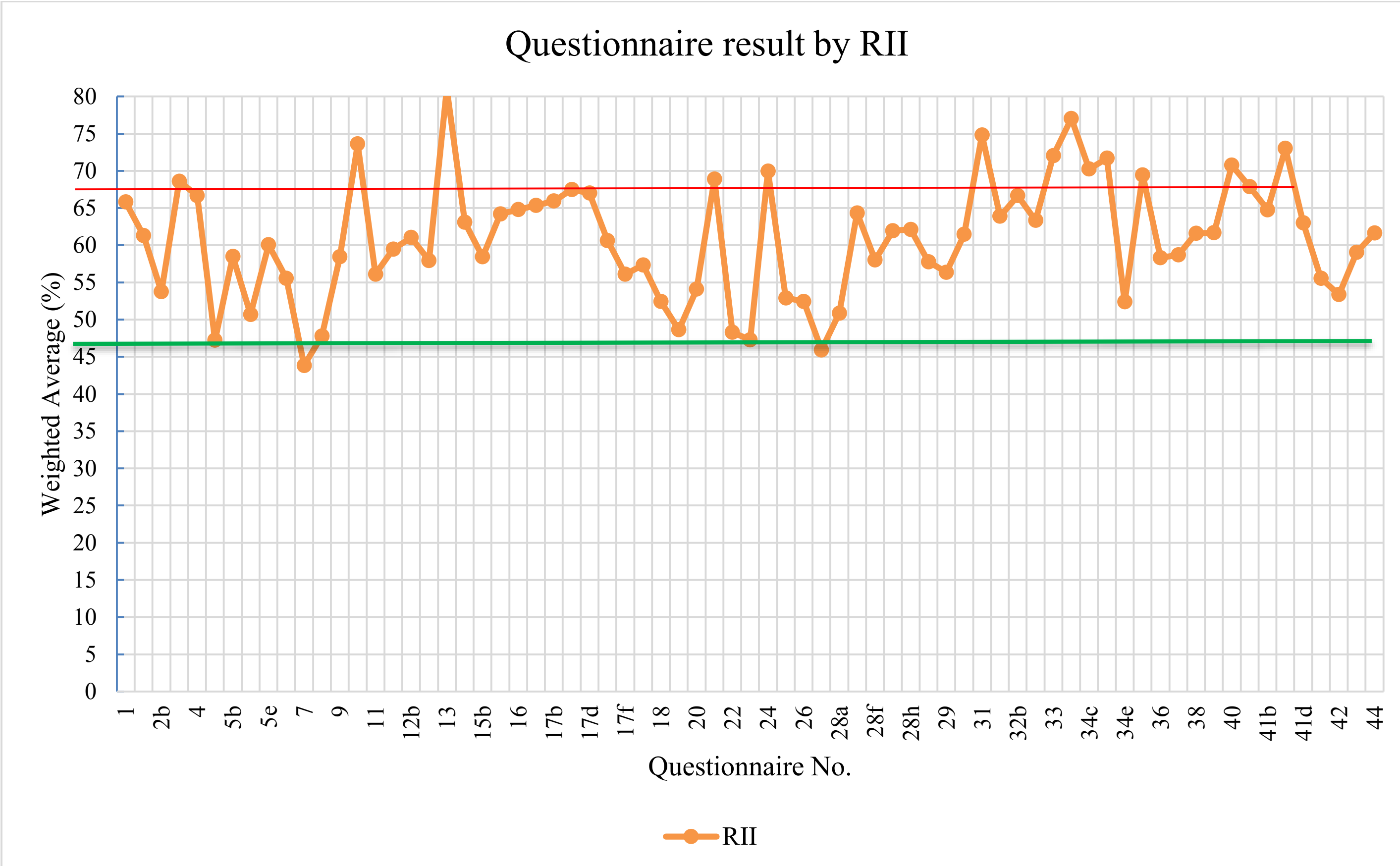


Figure 4.2: Result of questionnaire using RII

From the result of the first part of the questionnaire, which is the closed questioner, the most critical factors that influence management of deep excavation are screened out by rank of their result of relative important index. As we can see in figure 4.2 the result shows that the factors mentioned in questioner have high intensity of occurrence as per the RII analysis which describes how much the deep excavation construction in A.A. lack good execution management practice. More than 90% of the factors get results above 50% or greater than 0.5 RII which are labeled above the green line. This shows that the local practice in terms of management of deep excavation in all three phases, i.e. during planning, execution and monitoring and evaluation stage is facing challenges.

For this research purpose, the factors found above the red line in figure 4.2 are selected for discussion and they are presented in table below.

Table 4.2:- Top ten factors of deep excavation

Factors in execution of deep excavation	**RII**	**Rank**
Lack of planning to engage safety and health management	0.810	1
Lack of recording construction events that focus on Soil characteristics	0.770	2
Lack to implement safety and health management plan	0.752	3
Lack of adopting appropriate construction works methodology	0.736	4
Lack to perform monitoring for risk control through incorporating an inclusive quality control program during construction	0.730	5
Lack of close supervision and construction control	0.721	6
Lack of recording construction events that focus overhead & underground utilities	0.717	7
Lack of allocating support system for workers	0.708	8
Lack of recording construction events that focus on: Sudden drop of drill fluid or water gushing out(artesian) if any	0.702	9
Lack of recording the present status of the existing structure	0.700	10

1. The primary factor found to be the lack of planning to engage safety and health management that comprises identifying the hazards, assessing the risks to the work & staffs and determining appropriate control measures in consultation with all relevant stakeholders in the work. Thus in planning phase forecasting of risks is important. The risks are likely to be the presence of ground water, ground movement due to excavation, sliding of the ground, presence and protection of underground utilities with their impact on workers and the work itself and so on but they are neglected. As indicated in the literature review part, for deep excavation safety and health are forecasted and planned by comprising regulations especially with respect to confined that shall be designed & certified by professional engineer.
2. Lack of recording construction events that focus on soil characteristics is the other top factor that results unwanted effect in deploying deep excavations. Sufficient depth soil investigation to know the correct soil characteristics is mandatory before design that helps the designer to use the correct geotechnical data for his/her design which makes the design more practical. From the literature review, it is very important to have an effective instrumentation and monitoring scheme to make sure

that during excavation and construction of the underground structures, the safety of the surrounding properties can be secured. The instrumentation and monitoring scheme also allows the design engineer to validate the design and to identify the need for remedial measures or alterations to the construction sequence before the serviceability of the retaining or the surrounding structures and/or services are affected.

3. In third stage problem that is found in execution phase, which is lack to analyze the application of safety and health management system. Even if it is planned to use safety clothes & equipment the implementation is very rare. Though there is little improvement in implementation of safety equipment and overall safety management of most our contractors and consultants don't use safety clothes and equipment. The attitude of incurring additional cost in using such equipment isn't purely changed. Still in our construction industry analyzing of cost for using this equipment and costing for medicating injuries and rectifying accidents aren't performed and the out coming benefits aren't defined.

Figure 4.3:- Lack of proper usage of safety & health cloths

4. The fourth factor is lack of planning appropriate construction works methodology. The construction methodology shall be planned in suitable manner for workers. Allocation of machineries and materials, procedures of activities, how to excavate deeper without disturbing the surrounding ground, structures and so on must be studied and planned before handing over to execution. However, the consultant and design engineers do only the design of the structure to be constructed with deep

excavation but the methodology starts to be observed when construction is ahead and problems being observed. Improper execution brings accident to workers and wastage of resources. As described in the literature construction works methodology defined in the design stage as one major task so that planning of construction procedure, arrangement of site, locating of mobile equipment, stability of adjacent structures and related points have to be done by design engineers & other professionals with consultation of all responsible personnel. This allows to see the means to define contingency action plan for problems or failures that might occur.

5. The other cause brings out to be lack to perform monitoring for risk control through incorporating an inclusive quality control program during construction. One of the major tasks that should be performed in executing deep excava tion is monitoring risks to attain qualified output with efficient utilization of resources. By any means especially for underground structures planned quality should be attained precisely. For this it is important for the designer to communicate full design criteria to all parties involved in the construction and to monitor the quality of the work throughout the construction.
6. Lack of close supervision and construction control is factor for unwanted effect in monitoring phase. The construction and workmanship shall be closely supervised by the consulting engineer to ensure that the construction attains safety and quality which complies with drawings, specification, standards and use of the approved method.

Figure 4.4:- Unsafe & inappropriate working condition; poor reinforcement placement

7. Lack of recording construction events that focus on overhead & underground utilities is the seventh major factor that inhibits well implementation of deep excavation work. The presence of these utilities affects the construction work by any means. Mostly our cities underground utility lines exact location is not known. Most of utility providing companies have no plans that show their exact locations. This makes the designers to have no information of the locations so that they can't design with the consideration of protecting the utility lines. Thus the engineers prepare their design by guessing the locations therefore, as the excavation work begins it becomes difficult to directly interpret the design to construction, the utilities comes out as obstacle. This can be seen in the figure below (Figure: 4.8). So that studying of their locations, impact in construction & means of protection should be well defined. As a result lacking such information may result up to change and rework of design. So that close supervision with recording of events can results the protection of underground utilities.
8. Lack of allocating support system for workers appears to be the factor for the consequence of injuries of workers. Mostly supportive (temporary) works are ignored by our contractors for the purpose of cost reduction and the consulting engineers doesn't force the contractors to implement as necessary items. This is because of the attitude of less value given for workers particularly unskilled staffs even though international safety & health regulations obligate to allocate support systems and to assure their safeness.
9. Also lack of recording construction events that focus on sudden drop of drill fluid or water gushing out (artesian) is factor that results challenge. Such monitoring action is not accustom in A.A. deep excavation work unknowingly or ignorantly. As of this, recording events can lead to forecast damages as instability of the ground that could come out of artesian pressure and can allows for defining preventive solution.
10. The last but not the least top ten factor is lack of recording the present status of the existing structure. It isn't accustomed to address prediction of the status of bordering structures. Mostly it's considered as performing unnecessary work and costing extra amount. Even if it is the responsibility of the construction party to protect it. But the real fact isn't this, after accomplishment of excavation work problems started to appear where that require additional analysis, work and cost to solve existing problem. Also to protect further challenges.

In addition to interview and site observation the following points are perceived. As of local construction industry the quality assurance done for construction materials observed in the research is as a good trend. During the construction of deep excavation it's usual to construct temporary structures as shoring with pile for temporary support of the natural ground for projects that cover large area especially in areas where there is adjacent structure like building and main road.

Figure 4.5: Shoring pile for the support of natural ground

On the other hand, quality of fresh mixed concrete checked with slump test and compressive strength test also checked with cube tests. This is done in 70% of the observed sites; the slump test done per a truck mix delivered on site and cube test done per 100m^3 of mix of concrete.

Figure 4.6: On site slump test of concrete

In most of road projects usually short period is given for the design stage, whatever kind of project (huge or small) planned to construct which shows there is no emphasis given for the design. The 'make it quick' principle results unsafe design, unsafe structure and unsafe working environment. Correspondingly there is lack of soil investigation only test pit data are done, no pre design investigation because of poor understanding about geotechnical investigation output and importance. Specially, for deep excavation that need to be constructed in urban area proper soil investigation is very important but everyone's focus is on the cost incurred to perform the investigation. Most clients require investing less amount of money as much as possible & the consulting engineers don't force their clients. Thus, in order to avoid additional cost the preferable and most practicable way is to ignore it and do the design without having sufficient investigation. Therefore, the drawback isn't limited to design but also goes to construction.

The other point is with respect to construction work methodology, it usually comprises the procedure of tasks, the description of protection means of nearby structures, the limitations of using excavation machineries, scheduling every task required (w.r.t material, budget, etc...). Most contractors submit their construction methodology but remains on paper since they aren't studied well and difficult to be implemented. Also the consultants doesn't evaluate and question the practicability of the methodologies. Even if, the contractors provide work schedule, it's usual to work by trend which makes the work very difficult to manage. Besides all mentioned shortcoming, in almost all projects that engage in deep excavation work face cost over run and time extension as major challenging issues.

Figure 4.7: Lack of protection wall & sliding of the ground results collapse of the fence

In the figure 4.7, the contractor was the owner of the project who have no experience in deep excavation work. This contractor got high grade construction license but lacks work experience and experienced professionals for the deep excavation work. So it was very difficult to handle it. The excavation started at one time then left as it is for months. After that again the excavation started but done without providing any support to the ground and following proper construction procedure. Whether the excavation doesn't preserve the angle of repose of the soil or don't protect it with bracing or shoring. Thus, the soil slides down and cover the casted concrete foundation structure, also the sliding collapses the fence. Similarly the foundation structure covered with water because it's left ignorantly. While to continue the construction it is obvious how much it would cost.

As the primary isssue of this research is to investigating the local practice of execution of deep excavation construction in different projects, the A.A underpass light railway is the other one to consider. During execution of this infrastructure most of the work is done as per the design and plan. But some challeges were observed like safety problems, time extension, cost over run and right of way problem.

In most of road construction sites right of way problems which wasn't considered during design that requires design revision during execution phase appeared. Also poor site fencing were observed which leads to falling down of vehicles and pedestrians into the excavated area that results in different accidents up to death of persons.

During the execution of deep excavation, larger injuries were reported around kality, legahar, mexico & St.Lideta areas. The problems were related to safety that results death of more than five persons and high injuries of more than ten individuals recorded. The cases were due to sliding of the excavated soil, poor construction management corresponding to site fencing, arrangement of construction materials, arrangement of equipment in the project site and also lack of security & safety of workers.

In most of the assessed projects, geotechnical investigation done with the available professional. While the contractors ignore to consider and implement the results. Due to this contractros lack to know the specific type & cohesiveness of the soil that leads to ground related challenges. Sliding of the ground is one of the challenges, the reason behind this lack of defining cohesiveness of the soil which leads to determine the angle of repose during excavation. Cutting of the ground without keeping the appropriate angel of repose results sliding of the ground. From the data found in one of the projects mentioned above where death of persons recorded, the cause of failure was due to sliding of excavated soil in to workers who were inside to drill the rock using vibrator of the excavated area.

On the other sites, the failures were due to poor site fencing which leads to falling down of a kid into collected water of deeply excavated site. Also breaking of pully rope, unsafe rear driving of dump truck and poor site fencing are found as major reasons. [24]

The other concern is the weather condition, deep excavation of most road project and some of building projects visited were performed in rainy season, which makes the construction more challenge. In most of A.A. area the sub surface soil found to be soft clay from the result of geotechnical investigation and observation during site visits. In projects that were executed in dry season, the instability of the soil wasn't as such difficult and easily manageable. While those projects that were being executed in summer season faced stability problems of excavated ground. Since clay soil loss its strength as it gets wet it requires additional precaution to prevent the consquence of instability, that could be provision of supporting system to attain stability of the soil.

During interviewing of professionals engaged in railway project, it's found that there were big gap in implementation of safety and health management. More than 70% of the challenges were occured due to safety and health while this problems observed the assigned professionals engaged in the project were enforced to assign traffic and safety coordinator (TSC) to secure workers and neighboring society. After the deployment of TSC related problems and traffic congestion have been minimized. Risk identification related to the work wasn't developed during planning by identifying the actual situations.

The other issue in railway project found to be time extensions, as reported by the interviewee the time extensions were due to right of way and addition of work items. By the time of planning of construction the right of way issue wasn't analyzed thus during execution it appears as challenge and forced to incure additional cost. Extending the project from the initial scope created additional work items that resulted extension of time which also increased cost of the project. In one construction area of the Light rail way project that engage deep excavation water leakage found as problem. The ground water was found to be near more than expected, even if water proofing membrane was used, it wasn't effective. Thus, the construction crew use other means of technology as shotcreting of cementious water proofing to prevent the leakage of the leakage.

Figure 4.8: Practice of AALRT projects; lack of dewatering & protection nearby structure

In the local construction industry in most of the deep excavation projects uses specification and standards as guideline for quality assurance & construction methodology of overall excavation work and supporting structure construction presented below.

- BATCODA technical specification & designers specification which gives recommendation of the steps of excavation and bracing technique
- ERA specification & AACRA manual construction specification
- FHWA (Federal Highway Agency) & British standards
- AASHTO
- DIN
- FIDIC technical specification
- European standards plus software's like Plaxis & DeepXcav

In addition to these standards, other excavation management standards are used. Also check lists & construction manuals which are prepared by individual organizations including professional's experience are implemented. From the information gathered through interview & observation the trend of using checklist and quality manuals isn't as such remarkable. Commonly the checklists are used in 75% of sampled projects but the construction or quality assurance manual is used in only 40% of the assessed projects. These manuals are most of general standards which aren't quietly adopted for the specific work and condition of the project.

4.4. Problems and Challenges in the Execution of Deep Excavation

In this section the problems and challenges commonly found in A.A. Deep Excavation work will be discussed. Repeatedly mentioned challenges are found to be safety and health management, lack of recording construction events, wrong calculation of earth pressure and lack of well qualified and experienced professional and failures as differential settlement & cracks on bordering structures, collapse on adjacent structures including small injuries up to loss of lives of workers and neighboring society has been found as outstanding ones.

Besides the data collected from the questionnaire, other problems & challenges practiced by respondents that are specified as technical and non-technical challenges are evaluated with RII and ranked below.

Table 4.3:- Technical & Non-Technical challenges in deep excavation

Factors in execution of deep excavation	RII	Rank
Technical Concerns		
Inadequate instability analysis of an open cut excavation	0.616	8
Insufficient toe penetration of sheet piles	0.638	7
Wrong calculation of earth pressure induced by soft soil	***0.732***	***1***
Wrong calculation of Water pressure, Seepage force, Artesian water pressure, Squeezing/soil flow & Heaving	0.669	6
Inadequate performance of the wall (including the anchoring system)	0.592	9
Damage during the installation of the retaining wall	0.444	14
Incorrect assumption type, dimensions or quality of the foundation of adjacent buildings	0.589	10
Lack of adequate knowledge & experience of working staffs	0.586	11
Lack of proper dewatering procedure	0.533	12
Lack of proper reinforcing steel placement	0.375	15
Inadequate soil nailing and shotcreting	0.476	13
Non-Technical Issue		
Lack of proper management of bidding system	***0.692***	***4***
Lack of adequate evaluation of technical qualification of bidders	***0.710***	***3***
Difficulty to use lowest bidder wins system which results:		

• ***Inability to assign & pay qualified engineer***	***0.714***	***2***
• ***cutting overhead cost & ignore cost of temporary works***	***0.687***	***5***

Similar to the section 4.3, Relative Important Index (RII) of challenging factors calculated and highly ranked items that have greater values RII are highlighted for detail discussed.

As it is observed in the table above, the most frequently occurring problem is Wrong calculation of earth pressure induced by soft soil which is a technical issue that have been discussed in the above section and can be elaborated with one project which face failure.

Wrong calculation of earth pressure due to soft soil is resulted as factor of failure in deep excavation work. In designing a retaining structure to support the sides of an excavation, the magnitude and distribution of the stresses and movements likely to be induced in the structural components must be well estimated. Based on the geotechnical result identifying the cohesiveness of the soil and checking of angle of repose of the ground shall be well analyzed before proceeding to excavation. Both temporary and permanent works of deep excavation should be considered in depth before proceeding to construction. While precise calculation of earth pressure by the qualified geotechnical engineer allows to determine the suitable support system that preserves the ground movement.

Figure 4.9: Wrong calculation of soil pressure results in sliding & failure of foundation

As seen in the above figure (Fig. 4.9), which was one of the observed under construction site, faced sliding & failure of foundation due to wrong calculation of earth pressure. Since they got wrong result they ignored constructing temporary supporting structure. Thus, the soil of excavated side slides highly and covers the reinforced concrete footing pads with the reinforcement bars of the foundation columns. Only the top of reinforcement bars of the foundation columns left uncovered as symbol. Even though ignoring of supporting structure was done to reduce the construction cost, in actual condition the cost wasn't reduced rather increased to rectify the damaged foundation structure and to construct retaining wall to avoid further collapse.

In the same manner, the other visited site encountered similar challenge as shown in the figure below (Fig. 4.10). Wrong calculation of earth pressure resulted sliding of more than 6m horizontal ground and falling down of temporarily constructed facility rooms and collapse of foundation structure found.

Figure 4.10: (A) Sliding of ground due to wrong calculation of earth pressure

Figure 4.10: (B) Sliding & collapse of structure due to wrong calculation of earth pressure

In one of the observed site, shown in Figure 4.11 (a), the stakeholders tried to avoid the construction of temporary support structure since they have wrongly calculated earth pressure result. Meanwhile, it resulted in high ground sliding & collapse of nearby feeder road occurs. Then to rectify and prevent further failure they take immediate remedial action, construction of concrete retaining wall, which wasn't planned & designed before. Thus they incurred additional cost for this.


(a)

(b)

Figure 4.11: Sliding effect on utility lines and the sliding results unsafety environment neghborings

On the other hand, the consequence of avoiding this item of work besides the cost isn't analyzed well. Hence many injuries, construction failures and damages observed. The problem started from sliding of ground which results failure of feeder road, nearby structures, utility lines, and collapse of reinforcement bars installed for construction of foundation.

The others top five challenges are non-technical issues that are found to be very critical problems in execution of deep excavation work. The secondly and thirdly ranked factors of challenges are lack of adequate evaluation of technical qualification of bidders and difficulty to use lowest bidder wins system which results Inability to assign & pay qualified engineer.

The second mostly observed cause of challenges is found to be difficulty to use lowest bidder wins system which results inability to assign & pay qualified engineer. In the local construction industry the bidding system that is being practiced is the “lowest bidder wins” system which has negative consequence in attaining qualified and well experienced professional. Contractors and consultants can’t pay qualified engineer in a reasonable manner, they don’t have enough budgets to deploy the knowledge and experienced of their professionals as they win projects with least bidder. As a result it limits them the accomplishment of safety and quality of a given project by disbursing available resources effectively & efficiently. The outcomes turn out to be poor management of safety and health, lack to adopt appropriate construction works methodology, missing the assessment of hazards, failing to assess the present status of adjacent structures, presence of overhead & underground utilities & their effect on deep excavation work and so on. Thus the major means of failures or unwanted effect resulted due to lack of engaging experienced & well educated professional. Hence, the reason that forces to lack such professional should be well analyzed and rectified.

The third most frequently practiced challenge found to be lack of adequate evaluation of the technical qualification of bidders. In most projects technical qualification isn’t considered as the major factor for evaluation of bidders for deep excavation project. Since deep excavation requires special and well qualified professionals the technical qualification with respect to professionals, machineries, working methodology and experience in this specific construction work is very important. Awarding most qualified bidder can result safety and quality of work with effective utilization of resources, but in the local case this is rarely practical. Most bid evaluator’s focus on the budget offered for the work before the qualification. However such evaluations output doesn’t end at awarding stage but the effect shines during execution of the work by poor management of material, workmanship, schedule, safety and with poor quality assurance method.

The fourth one is lack of proper management of bidding system, poor bidding management system is one of the major cause of problem and challenge in execution of deep excavation. In almost all local construction industry less emphasis given for bidding system which results a number of problem in execution, while the effect exaggerates when we come to deep excavation. As explained earlier deep excavation implemented for the construction of huge & unique infrastructure that requires special care so that it requires the engagement of best suitable bidder found from proper bidding system. Once this system rectified it will solve other causes of challenge even non-technical and technical issues.

The fifth top factor challenge found to be difficulty to use lowest bidder wins system which results cutting overhead cost & ignore cost of temporary works, since one bidder come out with lowest bid then on the next it'll be forced to cut cost of some items to be least bidder, else it's difficult to include every items of work with profit. Thus mostly lowest bidders cut the temporary works which is very important item in deep excavation and also cut the overhead cost since they can't make their offer the least one. While they can't overcome the whole work without profit, so it's assumed to be engaged without profit though they don't work for endowment except to get profit whatever the amount it could be.

From the observation data, one of the challenges was to protect the adjacent structure. As a result of this collapse of two feeder roads found, in one of this roads the debris of the road demolishes the reinforcement bar prepared for the construction of foundation. To rectify this damage they went for the construction of retaining wall as shown in figure 4.12, which wasn't planned and considered before the collapse.

Figure 4.12: Construction of retaining wall

From the challenges occur during deep excavation work the respondents stated some additional factors other than mentioned in the questionnaire and presented hereunder:

Table: 4.4:- Factors of challenges

No.	Factors of challenges	Response rate
1	Lack of well qualified and experienced professional for the work	6
2	Lack to allocate specialized tools & equipment as per the required need of the project	3
3	Poor planning of work	3
4	Design problems; incomplete and non-detail design	3
5	Poor capability in performance by the contractor & consultant	3
6	Poor design consideration & poor geotechnical investigation schedule for the projects	2
7	Poor communication between main & sub-contractors and also with consultant	2
8	Lack of experience of machine operators & failure of machineries	2
9	Lack of identifying location of utility lines in advance	2
10	Lack to assess the presence & level of the ground water table	2
11	Lack of experience for shoring work and keep shotcrete wall thickness with fixing of reinforcement bars behind the pile	2
12	Lack of proper site management	1
13	Frequent change of demands from clients after starting of the construction that affect the original design	1
14	Lack of selecting appropriate type of foundation and deciding foundation depth	1
15	Lack of monitoring the status of the work & adopting monitoring instrument	1
16	Problem in using design standards & quality assurance manuals	1
17	Lack of deploying sufficient budget for intended works	1
18	Lack of full construction document	1
19	Problem regarding the type of work required for the project	1

Figure 4.14: Deformation of re-bars due to sliding of the ground & presence of ground water

In another scenario, in A.A. construction projects mostly we face very high potential of collapse or failure of excavation. When the failures first observed the responsible professionals haven't take any action to rectify or prevent further damages. Then as we can observe in the above figure (Fig. 4.14) the sliding of the excavated soil continues and deforms the reinforcement bars placed to cast mat foundation and beams. Consequently, this challenge poses hazards to workers & equipment. On the other case, lack of securing the nearby structures during deep excavation resulted settlement of the surrounding ground that created large cracks on the main joints of nearby building. This creates discomfort to the society to those who uses the buildings. Such challenges are shown in projects observed in figure below (Fig. 4.15).

Figure 4.15: Effect on neighboring structure

Accordingly these failures occur due to different problems & challenges stated in the questionnaire and also described by respondents. The challenges described by respondents are presented as follows:

Table: 4.5:- Failures or Damages mentioned from respondents

No.	Failures or Damages	Response rate
1	Differential settlement & cracks on bordering structures	5
2	Collapse on adjacent properties; sliding of neighboring road; fail to protect foundation of neighbor building (building holds on air)	5
3	Structural failure of piles, overturning of some piles due anchoring with unstrengthen temporary structure and with unknown source of water flowing into the construction site	3
4	Damage to utility lines, as storm water lines due to losing their support	2
5	Damage of structure due to poor workmanship in constructing retaining structure & its backfill material	2
6	Failure of support structure	2
7	Sliding of shoring pile due to failure of shotcrete concrete	2
8	Falling down of shotcrete wall due to improper execution that result the surcharge pressure creates further collapse of the structure and accident for workers	2
9	Sliding of the ground	2
10	Collapse of retaining wall by sliding	2
11	Serviceability failure of nearby structure	1
12	Damage of structure due to unforeseen ground water	1
13	Collapse of building due to shear failure of the foundation soil	1
14	Failure due to sliding of excavated soil	1
15	Horizontal movement of foundation structures	1
16	Settlement due to construction procedure & inappropriate type of retaining wall	1
17	Fall down of HCB fence wall of neighbor during excavation and Sliding of ground	1
18	Torsional failure of canopies (cantilevers)	1
19	Failure to protect permeability of water through structures	1

Figure 4.17: Failure of temporary supporting piles including the anchor

As the problems presented in the literature review similar challenges have been recorded. Some of them where inadequate instability analysis of an open cut excavation which can lead to a slope failure, wrong calculation of earth pressure that leads to total failure of sheet piles (supporting) and collapse of adjacent road. Also some technical challenges are occurred in similar manner as inadequate instability analysis of an open cut excavation, insufficient toe penetration of steel sheet piles, the earth pressure induced by soft clay that was wrongly calculated, seepage force, artesian water pressure and squeezing/soil flow and heaving are some of the major factors for failure that are the outcomes of precise analysis of stability of excavated ground.

Figure 4.18: Effect on neighboring structure; collapse of feeder road

Figure 4.19: Poor quality of concrete retaining wall, improper erection of formwork results deformed structure

4.5. Improving the methodologies for better execution management

Even in complicated urban settings, deep excavation work have been deployed successfully by overcoming construction challenges, so that if proper implementation of design with sufficient investigation of the ground and proper implementation of plan during execution with adequate supervision, the challenges and failure can be minimized and improved. In the literature review the remedial procedures that shall be followed are described, in similar manner the remedial measures that can be practiced as minimizing and avoiding the above discussed problems and failures are gathered.

Thus some of the practiced and forecasted measures are pointed out by participating professional in the following manner:

Table: 4.6:- Remedial measures mentioned by respondents

No.	Remedial measures	Frequency
1	Perform adequately study the geotechnical investigation report with full design analysis.	5
2	Perform close supervision and quality control	5
3	Construct appropriate excavation protection wall or supporting structure	4
4	Commence with an approved & complete design of the excavation	3
5	Before commencing work perform detail assessment of hazards	2
6	Protect adjacent structures avoid risks and damages	2
7	Study the history of the nearby structure which can be used as input for the design	2
8	Selection proper execution methodology, starting from design to construction	2
9	Communication with responsible bodies to protect utility line before excavation starts	2
10	Perform backfill between the pile shoring structure and the permanent retaining wall to avoid further ground movement	2
11	Use of appropriate construction materials, equipment and qualified workmanship	2
12	Before starting of excavation protect the existing structure	1
13	Create good communication means between construction parties	1
14	Construct site specific retaining structure	1
15	Adopt the precise and safest construction means to get planned and designed quality of the work	1
16	Adopt proper planning in risk measurement, identification & mitigation strategy	1
17	Assign a competent person who must inspect the excavation work	1

Generally, when unforeseen conditions in executing deep excavation appears, seeking immediate & temporary solution to avoid damage on structures, workers & neighborhood is important. Thus, the following analysis procedures can be as remedial measures, those are:

- Study the actual situation,
- gather preliminary information,
- perform reconnaissance survey and site investigation,
- then execute design modifications if required and
- adopt new construction method that allows to keep safety and quality of the project.

In relation to this, emergency action plan has to be prepared jointly with the concerned parties. Thus in such events emergency response, back-up operations, and disaster recovery means shall be implemented.

When problems related to loading the remedy will be stress relieve. As per the information gathered and described above due to improper loading of excavated materials high failures are recorded up to death of workers, therefore appropriate management of excavated materials, manpower and equipment is mandatory. This proper management allows avoiding extra stress which wasn't considered in designing stage besides keeping the safety and wellness of workers.

In the case of ground or surface water exists in deep excavation project it requires treatment and the solution shall be proper dewatering i.e. pumping out the water to avoid mud which affects working efficiency of machinery & manpower. For the safety of workers, machinery and materials draining of construction site is important. It also helps to protect and keep the wellness of neighboring structure. As the ground (soil) becomes wet its resistance to the pressure decreases. Thus the stability of the soil becomes in question hence it can result failure of the soil and problem to the nearby structure. But this outcomes are understood lately as the problem exists. Therefore, checking the existence and level of ground water before construction ahead is the primary factor and allocating appropriate dewatering procedure is a must.

Figure 4.21: Collecting ground water through perforated pipes & pump out the collected water

As sliding of ground occurs immediate action should be taken to avoid further failure and attain safety of the project so that design re vision and construction of temporary support structure is compulsory. As shown below in figure 4.22 similar action has been taken & construction of concrete retaining wall is done to prevent further sliding.

Figure 4.22: Construction of protection wall to avoid future sliding & to protect the neighbor structure

Thus in deep excavation considering construction quality & safety as primary issue the intention of achieving cost efficiency should come later employers, consultants and contractors should believe in prioritizing the quality of construction, effective and efficient utilization of resource and then comes to the budget.

In summary, this part mainly focuses on solution that are practiced in A.A. deep excavation projects and practicable solutions forwarded from respondents of questioner and interviews. Also response to unforeseen situations and remedial actions performed are described from observed sites.

5. CONCLUSIONS AND RECOMMENDATIONS

This chapter of the study deals with the conclusions and recommendations which are drawn a result of findings of the practice, challenges and corrective measures of the problems associated to execution management of deep excavation in Addis Ababa construction projects.

5.1. Conclusions

Due to congestion of construction area for expansion of roads and parking space of buildings in Addis Ababa, underground space are required and results deeper excavation which is developed in greater speed with the existence of bordering structure in either side of the project which makes the excavation work more challenging.

It is a fact that as we go deeper there is always uncertainty and challenges which could appear in one or another way. The concern isn't the existence but the prevention and avoidance of accidents & failures. Thus, this study aims to address the practice and challenges of deep excavation and to develop remedial solution. The primary theme is to get full and well studied technical documents & non-technical information, then forecast the upcoming difficulties of the specific project, which allows to revise the design and work methodology to achieve better execution management. From the discussions of the previous sections it appears to suggest that the local construction industry accomplish deep excavation inefficiently.

Execution management of deep excavation in A.A is implemented with a number of challenges that come out from lack of knowledge, lack of experience and also negligence to key subjects. As a result of the findings above, there are some good practice in implementation of design and attaining of quality with efficient utilization of resources. But mostly there is lack of accomplishing studied work specially with regard to substructure investigation, safety & health with application of risk management that sacrifices the quality, budget, time & safety of the work and workers.

One of the major findings is that safety and health management problems. The analysis illustrates that there is weakness in planning, implementing and monitoring safety and health management in this construction work. Although there is a bit practice to use safety equipment and protection of ground movement to avoid related risks, mostly related problems exist and are addressed after their occurrence resulted damages. Since deep excavation in A.A. is performed in congested area, serious attention is required and calls for improvement to save consumption of extra resources of the construction including human life.

The research conducted through gathering all reliable secondary data & studying them for literature review and collect primary data with interview, questioner and observation of A.A. construction projects practice. Following this analysis of findings with developing conclusions and recommendations accomplished.

It is found that most clients doesn't understand the output and benefits of geotechnical results and aren't willing to cost for the investigation. Since insufficient soil investigation results unexpected ground condition, it results revision up to change of design & work methodology that leads to incur additional cost and time for execution. This makes the management of deep excavation more challenging. But if there were reliable information, risks could be reduced and related problems could be defined ahead with an alternative corrective approaches. By this most of technical challenges could be address.

For protection of structures, construction of temporary retaining or supporting wall done. In building projects usually concrete shoring piles are used but in some cases employers push contractors to avoid such work for budget reduction and lately accidents and failures occur then unexpected cost generated. In underpass road & railway construction deep excavation implemented in better manner regard to buildings. But in all the three sectors considering & application of protection of neighboring structure, safety & health planning with overall management is very poor including information gap that appears between professionals.

Another major concern is monitoring and evaluation of the construction work with close supervision that is key procedure in deep excavation execution. Since it is applied to ensure the execution of construction complies with drawings, specification and approved work method to attain quality output in every aspect, the implementation requires great emphasis and improvement.

As remedial measure, adopt & perform adequately studied geotechnical investigation report with full design analysis, adapting close supervision and quality control, constructing appropriate excavation protection wall or supporting structure, revising working methodology with implementation of immediate corrective action are taken.

Besides the challenges and failures recorded in the execution, there are also appreciable practices with respect to assuring quality of construction materials. In almost all projects in road, railway and building deep excavation construction every construction material used by checking standard quality tests.

5.2. Recommendations

Despite the fact that deep excavation construction in A.A. is being deployed in congested area where there are structures nearby it needs improvement. Professionals and every participating parties should work to have better and enhanced means of execution. As per the outcome of the present research analysis and findings the following recommendations are forwarded:

1. Planning and implementation of safety and health management system to protect workers and the neighboring society is expected from consultants and contractors.
2. Contractors should plan, prepare and implement achievable work methodology by allocating relevant time and budget with available workmanship, machineries and other resources.
3. To protect facilities and workers, timely recording of construction events to accurately report key measures as survey of existence and status of bordering structures, utility and so on before commencing the excavation work is mandatory.
4. Contractors should plan to perform periodic evaluation of the performance of equipment used during excavation that allows to minimize and control challenges related to equipment failure.
5. Contractors should perform execution of deep excavation by having detail and approved design with all relevant information given from the design professionals.
6. Geotechnical engineers should perform detail geotechnical investigation & contractors should avoid ignoring such investigation reports. Contractors shall interpret the results and other design analyses with all design professionals. This can allow them to address the possible upcoming challenges.
7. Every contractor and consultant who are engaged in deep excavation work should perform field tests for every stage of excavation to ascertain the compliance of geotechnical result that can allow to revise design and work methodology for best execution.
8. Consultants and Regulatory bodies should prepare advanced controlling scheme aiming reduction and ultimately avoidance of problems occurring and assurance quality of the execution that allows to improve and upgrade the overall execution of deep excavation with respect to quality, cost, time and safety.

9. Regulatory bodies are required to give emphasis to such special and basic construction work and follow up the design & execution compliance in regard to safety & quality of the project, safety of neighboring society, protection of nearby structures and similar matters with the existing regulation and shall develop supportive guidelines or regulation to improve execution management and also the construction industry.
10. Employers are required to adopt contract documents that shall incorporates detail & clearly stated special conditions of contract and specifications which includes requirements for deep excavation to precisely address precaution measures.
11. Employers, consultants and contractors are required to prepare templates for recording data's of stability and deformation analysis, the degree of their existence and their effect on bordering structure and neighboring society and documented for future studies. Also such documentation can be used for evaluation of the execution management of deep excavation and improving the practice.
12. As many of the geotechnical investigation result and the execution practice shows that most of A.A. ground soil soft clay which lose its strength as it gets moist though for improved means of construction adopting deep excavation in dry season could create better condition for executing and managing deep excavation.
13. Professionals who are engaged in deep excavation shall have adequate knowledge and experience who can be problem solving in every stage of execution and also shall create good communication and partnership between all parties of deep excavation to easily address the challenges and cultivate alternative solutions mutually.
14. Updating professionals with training and education expected from construction companies for those who involve in design, execution and monitoring phase is more important to develop their skill and capability of solving problems regarding every aspect to create better execution management method.
15. Educational institutions shall give emphasis for this basic construction work and provide and students through project management courses both at the undergraduate and postgraduate levels, with an emphasis on risk analysis and execution management.
16. In addition to the above, further future in depth study in extension of this research work are recommended as:

- Assessment of performance of contractors and consultants in executing deep excavation for building, road and railway projects in A.A.
- Assessment of bidding system and evaluation of qualified bidders for execution and management of deep excavation construction
- Assessment of the involvement and contribution of regulatory bodies in the controlling and evaluation of the execution of deep excavation construction.
- Assess the advantage of implementing Building Information Model (BIM)database technology for risks assessment and management of monitoring data of deep excavation in urban areas.

17. Since we are compensating many resources up to human lives due to poor management, every professional who are engaged in the design, execution and monitoring should feel responsible and shall work to improve the practice. And change of attitudes is the core point that we all should work on.

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APPENDIXES

Appendix A: Research Proposal

ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

MASTER'S THESIS PROPOSAL

IDENTIFICATION

Name: Semegn W/Yohannes (GSR/3921/05)

Faculty: Technology

Department: Civil and Environmental Engineering

Major: Construction Technology and Management

Title of Thesis: **EXECUTION MANAGEMENT OF DEEP EXCAVATION IN ADDIS ABABA CONSTRUCTION PROJECTS**

(ERA Regular)

December, 2014

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Abstract

Deep excavation is an important component of construction for the purpose of foundation and basements allocation of new buildings in urban areas and other facilities in densely built-up areas of construction. Presently, shortage of space for parking, public amenities and housing utilities has made necessary to use underground spaces. Therefore in this paper, it is planned to present the investigation of local practices in the planning, quality assurance services and execution of deep excavation for the construction of foundation and basement works.

Deep excavations in urban areas require special measures due to the presence of structures, underground utilities and other engineering constructions existing in the vicinity.This study will present the problems, challenges and unwanted effects observed during execution in order to improve the local practice.

Though, it reviews literature in related topics, conduct observation, interviews and case study of projects which are engaged in such type of construction work. Then with the analysis of gathered data it tries to develop appropriate guidelines in order to improve the planning, quality assurance services and execution methodologies of deep excavations for the construction of foundation and basement works.

Introduction

A rapid development of economy leads for further construction of infrastructures while the available construction areas are limited. Thus the construction requires much excavation for foundations and basement provision that embrace difficult design, complicated construction technology, vulnerability to circumstance and other complex characteristics.[3]

The construction of deep excavations in the urban environment is a technically challenging problem that requires the design, coordination and controlling of site characterization, design of excavation support systems, specification of responses to construction difficulties, preconstruction surveys of adjacent properties and utilities, field observations during construction, excavation installation and structure construction. [2] [6]

Although excavations are regulated by federal, state and local building codes, problems occur in the process of developing a site due to design errors, construction errors, construction accidents, striking unknown utilities, differing site conditions, unforeseen natural events, or delays in completion. These problems occur on many projects; however, in an urban environment, the result is very often. [2] [4]

Adjacent construction may be a nuisance to neighboring property owners (e.g. right of entry agreements, shoring, underpinning, and/or alterations to operations, dust, noise, felt vibrations, traffic congestion). Frequently, adjacent property owners claim construction-induced damage. For deep excavations, this damage may include a combination of building settlement because of a loss of lateral support, loss of use, business interruption, and structural damage.[2]

On the other hand, even if such construction task requires special attention with regard to safety and health in working sites, in many cases of local construction it isn’t addressed properly due to less understanding of the risk and negligence. This leads to the practice of unsafe and health risky working environment. This problem is mainly due to the lack of proper planning, implementation of the plan and insufficient follow up. Even though, in complicated urban settings, deep excavation can be deployed successfully by overcoming construction challenges.

Statement of Problem

In our county cities develop rapidly with construction, while the space above ground are becoming more & more precious. Due to this underground space is developed with greater speed followed by deeper excavation although the constraint of land makes the excavation work more challenging. Consequently, this part of construction requires special attention and management to avoid unplanned and unwanted result.

In most of local construction sites, during the execution of deep excavation sliding of the ground, getting unexpected substructure which have contrary characteristic to the geotechnical results, presence of unexpected water table, striking unknown utilities and so on makes the excavation more difficult. Also, because of negligence and less attention to safety and health results many accidents and injuries of workers incurred during deep excavation. This usually occurs due to less attention given to the execution management of deep excavation in construction.

Therefore, studying the current practice of deep excavation in local construction especially in Addis Ababa which leads to the above mentioned drawbacks and reviewing of regulations related to this issue is important to attain improved construction means.

Literature Review

A deep excavation into the ground is indispensable to create additional floor space to meet increasing space requirements for parking for multi-story buildings and for other structures at the city centers. Numbers of deep excavation pits in city centers are increasing every year. Structures in the immediate vicinity of excavations, dense traffic scenario, presence of underground obstructions and utilities have made excavations a difficult task to execute. An excavation is basic phase in the construction of foundations or basements. The process of an excavation may encounter different kinds of soils underneath the same excavation site from soft clay to hard rocks. During excavation, some soil types pose greater problems than the others. [1][7]

No matter how many trenching, shoring, and back filling have been done in the past, it is important to approach each new project with the utmost care and preparation. Many on site accidents result directly from inadequate initial planning. Waiting until the work has started to correct mistakes in shoring or sloping slows down the operation, adds to the cost, and increases the possibility of other excavation failure. Determination of site condition through site observation, test borings for soil type or conditions, and consultations with local officials and utility companies is important and should be the primary activities to manage difficulties related to deep excavation.[1][5][6]

With this section, it is planned to look for information on related topic from different sources. This includes studying of previously done researches and scientific journals written in relation to the execution management of deep excavation in urban construction. That helps to study the subject matter with better understanding and allows having thoughtful ideas for identifying challenges.

Research Objective

Objective

- Assessinglocal practices in planning, quality assurance services and execution of deep excavation for the construction of basement and underpass road works.
- Identifying problems, challenges, unwanted effects and gaps that need to be addressed to improve the planning, quality assurance services and execution of deep excavation for the construction of basement and underpass road works.
- Recommending interventions in order to improve the planning, quality assurance services and execution methodologies of deep excavations for the construction of basement and underpass road works based on the findings of the study.

Research Question

- What is the practice of Addis Ababa construction projects in the execution management of deep excavation work?
- What are the problems and challenges incurred with regard to execution management of deep excavation?
- How the gaps can be filled and can achieve improved methodologies in order to have better execution management means?

Research Design and Methodology

This research focuses on identification of major problems related to the execution management of deep excavation in urban construction and resulting outcome. Thus the researchmethodologyincludes reviewing literatures, observation of undergoing construction projects, interviewing and conduct questionnaires for stake holders who directly participate in deep excavation work.

- **Literature Review**

  This will incorporated reviewing literatures in related topic and surveying researches on risk management of deep excavation done previously with emphasis given to local practice.

- **Population and Sampling**

  Identify the population size that will be addressed by this research and define sampling or sampling method of the population.

- **Research Identification**

  This will integrate preparation of questions, case observations, conducting of interview and/or questionnaires which are targeted to show the critical problems of the local practice in management.

- **Data Collection**

  Data's will be collected from observed cases, interviews and distributed questionnaires

- **Data Analysis**

  Finally the collected data's will be analyzed so that the resulting outcomes will be drawn as conclusion and recommendations.

Work Schedule

Item No.	Activities	Duration (Weeks)	2014	2015					
			December	**January**	**February**	**March**	**April**	**May**	**June**
1	Literature Review	**4**							
2	Population and Sampling	**3**							
3	Preparation of Question for Interview and Questionnaire	**3**							
4	Data Collection	**12**							
5	Data Analysis and Interpretation	**4**							
6	Preparation and submission of draft thesis	**6**							
7	Preparation and submission of the final thesis	**4**							

Budget

The total cost of the thesis is estimated to be**13,325.00** birr based on the activity plan. The detail cost breakdowns are depicted as follows:

A. Expendable Supplies and Documentation:					
Item No.	**Item**	**Unit**	**Quantity**	**Unit Price (Birr)**	**Total Price (Birr)**
1	Stationary Materials	Lump Sum			800.00
2	Flash Disk(8gb)	No	1	500.00	500.00
3	EVDO	No	1	1200.00	1200.00
4	Typing	Page	250	3.00	750.00
5	Printing	Page	250	1.50	375.00
6	Thesis Binding	Pcs	5	70.00	350.00
7	Photocopy	Page	1250	1.00	1250.00
	SUB TOTAL				**5225.00**
B. Transportation:					
Item No.	**Item**	**No of Trip**			**Total Price (Birr)**
1	Research Travel	Lump Sum			3000.00
	SUB TOTAL				**3000.00**
C. Communication:					
Item No.	**Item**	**Unit**			**Total Price (Birr)**
1	Telephone	Lump Sum			3000.00
2	Internet Service	Lump Sum			2100.00
	SUB TOTAL				**5100.00**
	TOTAL (A+B+C)				**13,325.00**

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Submitted by

Semegn W/yohannes	____________________	____________________
Student	Signature	Date

Approved by

1.	Dr. Wubishet Jekale	____________________	____________________
	Advisor	Signature	Date
2.	____________________	____________________	____________________
	Chairman, Dep.'s Graduate Committee	Signature	Date
3.	____________________	____________________	____________________
	Chairman, Faculty's Graduate Committee	Signature	Date
4.	____________________	____________________	____________________
	Dean, Graduate School	Signature	Date

Appendix B: Questionnaire

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Questionnaire Survey for Thesis paper on

Execution Management of Deep Excavation in Addis Ababa Construction Projects

The purpose of this questionnaire is to study practices in planning, quality assurance services and execution of deep excavations in addition to that to identify the problems and challenges incurred with regard to execution management of deep excavation in Addis Ababa construction projects. Please answer all questions as possible. All the information gathered will be kept confidentially and will be used only for academic research and analysis without mentioning the names of individuals companies involved.

Thank you in advancing for your precious time and kind cooperation!

Sincerely Yours

Semegn W/yohannes

Supervised by: -

Dr. Wubishet Jekale

General Information

Please add (☐) as appropriate:

1. Type of Organization (Respondents designation)

☐Client	☐ Consultant	☐ Contractor

2. Type of Project (Respondents designation)

☐ Building	☐Road	☐Railway

Closed Questioners

The given below are numbers of root causes for the problems, challenges and unwanted effects in deep excavation for construction projects in Addis Ababa. Please indicate the significance of each factor by ticking the appropriate boxes and add any remarks relating to each factor as alleviation majors such as the reasons, the critical factors &/or the solutions.

E.S. = Extremely Significant [4] V.S. = Very Significant [3]

M.S. = Moderately Significant [2] S.S. = Slightly Significant [1]

N.S. = Not Significant [0]

Question No.	Factors for the challenges and unwanted effects	E.S [4]	V.S [3]	M.S [2]	S.S [1]	N.S [0]	Remarks
Part 1. Planning							
Design							
1	Lack of design for the supporting system						
2	Lack of selection suitable type of retaining wall with respect to:						
a	- Ground condition						
b	- Limitation of nearby structure						
3	Lack of planning assessment of hazards before design						
4	Poor communication between design professionals; geotechnical engineer, structural engineer…						
5	Lack of considering ground related risks in design like:						
a	- Ground movement						
b	- Ground water level						
c	- Change in stress state in subsoil due to unloading & loading						
d	- Vertical & horizontal displacement of adjacent ground						

Question No.	Factors for the challenges and unwanted effects	E.S [4]	V.S [3]	M.S [2]	S.S [1]	N.S [0]	Remarks
6	Lack of designer's experience in construction works methodology						
Planning for Construction							
7	Lack of allocating site access (entrance and exit ways to the site) for workers						
8	Lack of allocating of sufficient construction budget & time						
9	Lack of allocating construction materials, workmanship & equipment						
10	Lack of planning to adopt appropriate construction works methodology						
11	Lack of planning to perform dilapidation (destruction) survey for nearby facilities						
12	Lack of planning to analyze the impact of construction on adjacent properties due to:						
a	- Lowering water table						
b	- Horizontal ground movement & Surface settlement						
c	- Displacement of retaining structures						
Health and Safety							
13	Lack of planning to engage safety and health management						
14	Lack of planning to identifying sources of risk related to:						
a	- Ground water table						
b	- Ground movement						

Question No.	Factors for the challenges and unwanted effects	E.S [4]	V.S [3]	M.S [2]	S.S [1]	N.S [0]	Remarks
c	- Settlement of adjacent buildings						
16	Lack of planning to analyze the present condition of existing structure						
17	Lack of preparing safety check list to analyze:						
a	- Traffic						
b	- Proximity and physical conditions of nearby structures						
c	- Soil type						
d	- Surface and ground water						
e	- Location of the water table						
f	- Weather condition						
g	- Overhead and underground utilities like supply of water, sewerage, telecommunications						
18	Lack of planning to allocate raising and lowering lifting machine to lower workers, like tripod						
19	Lack of select appropriate hoist (lifting machine)that shall be: designed and certified by a professional engineer & that have sufficient height and capable to support the assumed maximum load						

Question No.	Factors for the challenges and unwanted effects	E.S [4]	V.S [3]	M.S [2]	S.S [1]	N.S [0]	Remarks
Part 2. Execution							
Carry Out Construction							
20	Lack to develop outline of measurement techniques for risk in execution by defining: elements of the deep excavation, unwanted events affecting the execution, parameter& technique of measurement						
21	Lack of adopting planned construction works methodology						
22	Lack to use prearranged site access (entrance and exit ways to the site) for workers						
23	Lack to carry out back analysis of the existing structure with respect to State of serviceability of the structure, Appearance of cracks etc.						
24	Lack of recording the present status of the existing structure						
25	Lack of analyzing ground surface settlement occur due to: Retaining wall construction, Ground water pumping & Main excavation						
26	Lack of measuring key functions: like Surface settlement, Deflection of retaining wall						

Question No.	Factors for the challenges and unwanted effects	E.S [4]	V.S [3]	M.S [2]	S.S [1]	N.S [0]	Remarks
27	Lack of determining vertical & horizontal displacement						
28	Lack of analyzing impacts which cause displacements of retaining structures and settlements of the adjacent buildings like:						
a	with change of stress state in subsoil by loading &unloading process						
b	with type and technology of bracing system which define its stiffness						
c	with vibrations during driving/ vibrating of sheet pile wall						
d	with technology of excavation deepening						
e	with influence of dewatering & disturbance of groundwater flow						
f	influence of vehicular traffic						
29	Lack of analyzing the impact & difficulties for inhabitants						
30	Lack of accurate and on-time reporting of key measures						
Health and Safety							
31	Lack of implementing safety and health management						
32	Lack of analyzing the current condition of risk related to:						
a	- Ground water table						

Question No.	Factors for the challenges and unwanted effects	E.S [4]	V.S [3]	M.S [2]	S.S [1]	N.S [0]	Remarks
b	- Ground movement						
c	- Settlement of adjacent buildings						
Part 3. Monitoring and Evaluation							
Supervision							
33	Lack of close supervision and construction control						
34	Lack of recording construction events that focus on:						
a	- Soil type						
b	- Sudden drop of drill fluid or water gushing out(artesian)						
c	- Overhead & underground utilitie						
d	- Weather condition						
35	Lack to check records of instruments & carry back analysis to validate the design & performance of the wall						
36	Lack to check over excavation to avoid additional stress that increase wall movement						
37	Lack to check the surcharging at the retained side wall that might increase soil pressure						
38	Lack of examine prestressed ground anchors & carefully carryout locking off.						
39	Lack to check overstressing & understressing of anchor to avoid over load & movement						

Question No.	Factors for the challenges and unwanted effects	E.S [4]	V.S [3]	M.S [2]	S.S [1]	N.S [0]	Remarks
40	- Lack of support system for workers						
41	- Lack to perform monitoring for risk control through:						
a	- Incorporating a design with adequate safety factor						
b	- Reasonable ground movements that could be safely tolerated by the surrounding structures						
c	- Incorporating an inclusive quality control program during construction						
d	- Performing a pre-construction destruction survey						
e	- Weather condition						
42	- Lack of adopting contingency plan for events identified during execution of the project						
43	- Lack to use contingency plan of action for: emergency response, back-up operations, disaster recovery						
Part 4. Challenges							
Technical Concerns							
44	Inadequate instability analysis of an open cut excavation						
45	Insufficient toe penetration of sheet piles						
46	Wrong calculation of earth pressure induced by soft clay						
47	Wrong calculation of Water pressure, Seepage force, Artesian water pressure, Squeezing/soil flow & Heaving						

Question No.	Factors for the challenges and unwanted effects	E.S [4]	V.S [3]	M.S [2]	S.S [1]	N.S [0]	Remarks
48	Inadequate performance of the wall (including the anchoring system)						
49	Damage during the installation of the retaining structure						
50	Incorrect assumption type, dimensions or quality of the foundation of adjacent buildings						
51	Lack of adequate knowledge & experience of working staffs						
52	Lack of proper dewatering procedure						
53	Lack of proper reinforcing steel placement						
54	Inadequate soil nailing and shotcreting						
Non-Technical Issue							
55	Lack of proper management of bidding system						
56	Lack of adequate evaluation of technical qualification of bidders						
57	Difficulty to use lowest bidder wins system which results:						
a	- Inability to assign & pay qualified engineer						
b	- cut overhead cost & ignore cost of temporary works						

Open Questioners

1. Are there any other problems and challenges that you observe in performing such construction work? If there are please discuss them

   ____
   ____
   ____
   ____

2. What kinds of failures or damages have you faced to structures?

   ____
   ____
   ____
   ____
   ____

3. What remedial measures do you suggest or take in order to avoid such problems and challenges?

   ____
   ____
   ____
   ____
   ____

4. How do you respond to unforeseen conditions which appear during execution of deep excavation that might affect the quality of the project?

   ____
   ____
   ____
   ____
   ____

5. How and what kind of specification and/or guideline do you use for the execution of deep excavation?

   ____
   ____
   ____
   ____

THANK YOU!

Appendix C: Questionnaire Analysis

Question No.	Factors for the challenges and unwanted effects	RII
Part 1. Planning		
Design		
1	Lack of design for the supporting system	0.658
2	Lack of selection suitable type of supporting structure with respect to:	
a	Ground condition	0.613
b	Limitation of nearby structure	0.538
3	Lack of planning for assessment of hazards before design	0.686
4	Poor communication between design professionals; geotechnical engineer, structural engineer…	0.667
5	Lack of considering ground related risks in design like:	
a	Ground movement	0.472
b	Ground water level	0.585
c	Change in stress state in subsoil due to unloading & loading	0.507
d	Vertical & horizontal displacement of adjacent ground	0.600
6	Lack of designer's experience in construction works methodology	0.556
Planning for Construction		
7	Lack of allocating site access (entrance and exit ways to the site) for workers	0.438
8	Lack of allocating of sufficient construction budget & time	0.478
9	Lack to allocating quality construction materials, workmanship & equipment	0.585
10	Lack of planning to adopt appropriate construction works methodology	0.736
11	Lack of planning to performing dilapidation (destruction) survey for nearby facilities	0.561
12	Lack of planning to analyze the impact of construction on adjacent properties due to:	
a	Lowering water table	0.595

b	Horizontal ground movement & surface settlement	0.610
c	Displacement of retaining structures	0.579
Health and Safety		
13	Lack of planning to engage safety and health management	0.810
14	Lack of planning to identifying sources of risk related to:	
a	Ground water table	0.631
b	Ground movement	0.584
c	Settlement of adjacent buildings	0.642
16	Lack of planning to analyze the present condition of nearby existing structure	0.648
17	Lack of preparing safety check list to analyze:	
a	Traffic	0.654
b	Proximity and physical conditions of nearby structures	0.659
c	Soil type	0.675
d	Surface and ground water	0.670
e	Level & location of the water table	0.606
f	Weather condition	0.561
g	Overhead and underground utilities like supply of water, sewerage, telecommunications	0.574
18	Lack of planning to allocate raising and lowering lifting machine to workers, like tripod	0.525
19	Lack of select appropriate hoist (lifting machine) that shall be: designed and certified by a professional engineer that have sufficient height and capable to support the assumed maximum load	0.486
Part 2. Execution		
Carry Out Construction		
20	Lack to develop outline of measurement techniques for risk in execution by defining: the elements of the deep excavation, unwanted	0.541

	events affecting the execution, parameter & technique of measurement	
21	Lack of adopting planned construction works methodology	0.689
22	Lack to use prearranged site access (entrance and exit ways to the site) for workers	0.483
23	Lack to carry out back analysis of the existing structure with respect to State of serviceability of the structure, Appearance of cracks, etc.	0.473
24	Lack of recording the present status of the existing structure	0.700
25	Lack of analyzing ground surface settlement occur due to Retaining wall (supporting structure) construction, Ground water pumping, Main excavation	0.529
26	Lack of measuring key functions like Surface settlement, Deflection of retaining wall	0.524
27	Lack of determining vertical & horizontal displacement	0.459
28	Lack of analyzing impacts which cause displacements of retaining structures and settlements of the adjacent buildings like	
a	with change of stress state in subsoil by loading & unloading process	0.509
b	with type and execution method of bracing system which define its stiffness	0.643
c	with vibrations during driving/ vibrating of temporary supporting wall	0.580
d	with technology used to deepen the excavation	0.619
e	with influence of dewatering & disturbance of groundwater flow	0.621
f	influence of vehicular traffic	0.578
29	Lack of analyzing the impact & difficulties for inhabitants	0.564
30	Lack of accurate and on-time reporting of key measures	0.615
Health and Safety		
31	Lack to implement safety and health management plan	0.745
32	Lack of analyzing the current condition of risk related to:	
a	Ground water table	0.639
b	Ground movement	0.667
c	Settlement of adjacent buildings	0.633

Part 3. Monitoring and Evaluation		
Supervision		
33	Lack of close supervision and construction control	0.721
34	Lack of recording construction events that focus on:	
a	Soil characteristics	0.770
b	Sudden drop of drill fluid or water gushing out(artesian) if any	0.702
c	Overhead & underground utilities	0.717
d	Weather condition	0.524
35	Lack to check records of instruments & carry back analysis to validate the design & performance of the wall	0.694
36	Lack to check over excavation to avoid additional stress that increase wall movement	0.583
37	Lack to check the surcharging at the retained side wall that might increase soil pressure	0.587
38	Lack to examine prestressed ground anchors & carefully carryout locking off.	0.616
39	Lack to check overstressing & understressing of anchor to avoid over load & movement	0.617
40	Lack of allocating support system for workers	0.708
41	Lack to perform monitoring for risk control through:	
a	Incorporating a design with adequate safety factor	0.679
b	Reasonable ground movements that could be safely tolerated by the surrounding structures	0.648
c	Incorporating an inclusive quality control program during construction	0.730
d	Performing a pre-construction destruction survey	0.630
e	Recording Weather condition	0.556
42	Lack of adopting contingency plan for events identified during execution of the project	0.533
43	Lack to use contingency plan of action for emergency response, back-up operations, disaster recovery	0.590

Part 4. Challenges		
Technical Concerns		
44	Inadequate instability analysis of an open cut excavation	0.616
45	Insufficient toe penetration of sheet piles	0.638
46	Wrong calculation of earth pressure induced by soft soil	0.732
47	Wrong calculation of Water pressure, Seepage force, Artesian water pressure, Squeezing/soil flow & Heaving	0.669
48	Inadequate performance of the supporting wall (including the anchoring system)	0.592
49	Damage during the installation of the retaining structure	0.444
50	Incorrect assumption type, dimensions or quality of the foundation of adjacent buildings	0.589
51	Lack of adequate knowledge & experience of working staffs	0.586
52	Lack of proper dewatering procedure	0.533
53	Lack of proper reinforcing steel placement	0.375
54	Inadequate soil nailing and shotcreting	0.476
Non-Technical Issue		
55	Lack of proper management of bidding system	0.692
56	Lack of adequate evaluation of technical qualification of bidders	0.710
57	Difficulty to use lowest bidder wins system which results:	
a	Inability to assign & pay qualified engineer	0.714
b	cutting overhead cost & ignore cost of temporary works	0.687

Appendix D: Observation Guideline

Observation Guideline

Type of project

Building ☐ Road ☐ Railway ☐

1. What are the issues considered before commencing deep excavation execution?

 ____

2. Is there any standard and specific quality assurance manual adopted for the work?

 ____

3. What kind of construction methodology is adopted?

 ____

4. Does construction material test performed to assure quality of construction materials?

 ____

5. Does they perform periodic evaluation of equipment deployed for the excavation?

 ____

6. Did they provide temporary support to protect the excavated ground? On what basis?

 ____

7. What kind of supporting structure applied?

 ____

8. How quality does controlled in deep excavation work and the evaluation is done?

 ____

9. Do they protect nearby structures and how?

 ____

10. Is there any challenge occurred during execution? What types of challenge and how much was the damage?

 ____

11. How do they handle the challenges and what kind of precautions they adopt?

 ____

12. How do they respond to unforeseen conditions?

 ____

13. How do they manage unexpected ground conditions?

 ____

14. How did they manage the overall execution?

 ____

DECLARATION

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university, and that all sources of materials used for the thesis have been duly acknowledged.

Name	Semegn W/yohannes
Signature	_________________
Place	Addis Ababa University, Addis Ababa
	Faculty of Technology
Date of submission	June, 2016