ARAB ACADEMY FOR SCIENCE, TECHNOLOGY & MARITIME TRANSPORT

(AASTMT)

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EFFECT OF INADEQUATE SOIL INVESTIGATION ON THE COST AND TIME OF A CONSTRUCTION PROJECT

By

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Yemen

A dissertation submitted to AASTMT in partial
Fulfillment of the requirements for the award of the degree of

MASTER of SCIENCE

In

CONSTRUCTION AND BUILDING ENGINEERING

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2013

DECLARATION

I certify that all the material in this thesis that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this thesis reflect my own personal views, and are not necessarily endorsed by the University.

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بسم الله الرحمن الرحيم

قال تعالى

(وَمَا أُوتِيتُمْ مِنْ الْعِلْمِ إِلاَّ قَلِيلاً)

وقال جل وعلا

(نَرْفَعُ دَرَجَاتٍ مَنْ نَشَاءُ وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ)

و كَانَ النَّبِيُّ صَلَّى اللَّهُ عَلَيْهِ وَسَلَّمَ ، يَقُولُ

''اللَّهُمَّ انْفَعْنَا بِمَا عَلَّمْتَنَا، وَعَلِّمْنَا مَا يَنْفَعُنَا، وَزِدْنَا عِلْمًا إِلَى عِلْمِنَا "

DEDICATION

I dedicate this thesis firstly to my family especially; my parents for their love, endless support, encouragement, and their patient on my long absent; my sisters and brothers encourage me always to do my best. I also dedicate this thesis to my mother country Yemen and my second country Egypt.

ACKNOWLEDGEMENT

I would like to thank my thesis supervisor: Prof. Mohammed Emamto put me in the path to pursue in this thesisand for his encouragement, insightful comments.I also would like to express my sincere gratitude to mythesissupervisor and advisor Prof. HossamHosny for the continuous support of my M.Sc. study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not imagine having a better advisors and mentors for my M.Sc. study.

My sincere thanks also go to the department chairman Dr. AbdElmonemSanad, and Dr. AkramSoltan, for supporting me.

I would like to thank my guidance and supporter Dr. MarawanShehein who helps me a lot, and provides me by all the information that I asked for. I also want to thank my work colleagues Dr. WaleedOgila, Eng. NohaRabei for helping me in collecting data.

Last but not least, I would like to thank my loving parents, sisters and brothers,and my fiancé for being always there for me, and for supporting me throughout my entire master program

ABSTRACT

The appropriate information or data is the keystone of any successful design. In any engineering system, accuracy of the system output depends on the accuracy of the system inputs.

Soil investigation phase of any geotechnical design plays a vital role to provide the geotechnical engineer by the most appropriate data to ensure that the design data represent the investigated soil. The purpose of a soil subsurface investigation is to provide data concerning the engineering properties of the soil for a proper design and safe construction of a project. Soilinvestigation aims to reduce the uncertainty of ground conditions by various combinations of field and laboratory testing.

One of the greatest causes of foundation failure is due to insufficient knowledge of ground conditions. Uncertainty in ground conditions can cause significant cost overruns and time delays for both client and contractor.Insufficient geotechnical investigations are currently one of the most common sources of costly, overdesigned foundation, project delays, disputes, claims, and project cost overruns. Inadequate characterization of the subsurface conditions may contribute to either a significantly over designed solution that is not cost-effective, or an under designed, which may lead to potential failures.

The research main goal is to study the impact of varying the scope of a soil investigation on the cost and time of the construction projects. By quantifying this effect, a conclusion might be reached about the importance of the soil investigation, and how is the soil investigation cost minimum comparing to the sequences that might occurs due to ignoring such factor.

Unforeseen site conditions may have an impact on time and cost of construction project. Sometimes they may prevent the contractors form performing the contractual obligations, and other times they only make it harder or more costly to perform the contract.

The contract is the main reference in case of any disputes between the contract parties.The contract must be drafting in a way at which its clauses do not conflict with law. Another purpose for this research is to know how the issue of the soil investigation can be effectively handled in the Egyptian law and construction contracts respectively.

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NOMENCLATURES

Symbol	Nomenclatures	Units
COV	Coefficients of Variation	%
CPT	Cone Penetration Test	
q_t	Side Friction	MN/m^2
q_c	Cone Tip Resistance	MN/m^2
VST	Vane Shear Test	
s_u	Ultimate Friction Value	MN/m^2
SPT	Standard Penetration Test	
N	Standard Penetration Number	blows/ft
DMT	Dilatometer Test	
I_D	Inversed Distance Weighted	
K_D	From DMT Screen	
E_D	Elastic Modulus from DMT	MN/m^2
PMT	Pressuremeter Test	
P_L	Pressuremeter Limit Stress	kN/m^2
E_{PMT}	Elastic Modulus From PMT	MN/m^2
w_n	Natural Water Content	%
W_L	Liquid Limit	%
W_P	Plastic Limit	%
PI	Plasticity Index	%
LI	Liquid Index	%
γ	Bulk Unit Weight of Soil	kN/m^3
γ_d	Dry Unit Weight of Soil	kN/m^3
Dr	Relative Density	%
Var	Variance	
σ^2	Standard Deviation	
SOF	Scale of Fluctuation	

CHAPTER ONE

INTRODUCTION

1.1. OVERVIEW

In construction engineering, correct data is required for a successful design. Soil investigation (Also known as geotechnical site investigation, geotechnical investigation or site investigation) is the process of obtaining geotechnical and geological information in order to determine soil parameters for the purposes of the geotechnical or structural engineering design. Such types of investigations give a general idea about ground conditions including the thickness of each layer and existence of any problematic conditions. Subsurface ground investigations are performed only on a fraction of the project site because investigating the complete site would be extremely expensive. Based on the limited field and laboratory test results, estimates and judgment would be made about the ground profile that would have a great influence on the performance and costs of the structure on site. The scope of the soil investigation should be decided by the experts depending mainly on the variation of the soil in thesite. Other factors also should be taken to consideration like project type, cost, foundation type, building purpose, building loads, and prior knowledge of site subsurface conditions.

1.2. PROBLEM STATEMENT

Soil investigation is normally required and carried out prior to the starting of the design of a construction project. Due to the lack or the inadequacy as well as poor quality of soil investigation work, geotechnical failures may occur. One of the greatest causes of foundation failure is due to insufficient knowledge of ground conditions. Uncertainty in ground conditions can also cause significant cost overruns and time delays. A proper soil investigation is required for safe and economic design. The lack of data concerning the soil may lead to overdesigned and uneconomic foundation, or the structure might be underdesigned which means that a failure might happen.

1.3. OBJECTIVE AND SCOPE

Inadequacy of the soil investigation may lead to increasing the project total cost, or may cause an increase of the project duration which also leads to an increase in the project total cost. Any change in the soil investigation scope affects the uncertainty of the ground conditions. By reducing the ground conditions uncertainty, therisk of unforeseen conditions reduces. The research goalsare as following:

- Study the impact of varying the scope of a soil investigation on the cost and time of the construction projects.
- Prove that the soil investigation cost is minimum comparing to the sequences that might occur due to ignoring such factor.
- Studying the contractual and legal aspects of the soil investigation affect its responsibility, and then its scope. So, this research aimed also to study the legal and contractual responsibility of the soil investigation.

1.4. METHODOLOGY

After literature survey to discuss the previous research works in the studied area, the following methodology will be pursued to reach this thesis objective. The first part of this thesis deals with the case studies. In general, the analyses of the casestudies will be conducted as following.

a) Overview the project original soil investigations to determine the soil investigation scope.

b) Overview the original soil investigations cost.

c) Comparing original soil investigation cost with the typicalcost according to literature and/or codes requirements.

d) Evaluating the problems that occurred in the projects due to inadequate soil investigations.

e) Computing or (estimating if not available) the rehabilitation cost for these problems.

f) Evaluating the soil investigation needed to reach the acceptable knowledge for the site conditions.

g) Comparing the cost of extra soil investigations with the rehabilitation cost.

h) Overview the original project schedule, and determine if any delays occurs due to soil problems.

The second part of this thesis is going to deal with the contractual and legal aspects of the soil investigation. This part purpose is to search in the responsibility of the soil investigation. The responsibility covers the costof the soil investigation and any extra cost due to the inadequacy of the soil investigation, and the legal responsibility of any destruction.

1.5. ORGANIZATION OF THE THESIS

This thesis undertakes to quantify the effect of inadequate soil investigation on the cost and time of a construction project. Chapter 2 covers the existing literature survey to discuss the previous research works in the studied area. The main items of the literature review are:

- Characterization of Ground Conditions;
- Sources of the Uncertainty in Geotechnical Engineering;
- Previous Work on Effect of Soil Investigations; and,
- Responsibility of the SoilInvestigation.

Chapter 3 contains the six case studieswhich have been collected. Each case study will be described and analyzed. The main points that will cover in this chapter are:

- project description;
- original soil investigations;
- problem;
- causes;
- corrective action;
- original soil investigation scope;

- original soil investigation cost;
- estimating the typicalsoil investigation cost;
- comparing the original soil investigation with the typical one;
- problem and corrective action;
- extra cost due to this problem;
- comparing the extra cost with the cost of the typicalsoil investigation; and,
- time extension due to the problem.

Chapter 4 studies the contractual and legal aspects of the soil investigation. The main objective of this chapter is to study the responsibility of the soil investigation. Who should identify its scope, who is the responsible for taking it, and who is the responsible for any consequences due to its inadequacy or inefficiency? A questionnaire survey analysis has been conducted. The purpose of this questionnaire is to know how the issue of soil investigation can be effectively handled in the Egyptian law and the construction contracts respectively. The main points that cover in this chapter are:

- Responsibility of soil investigation in laws. An example for international laws has been taken. These examples are:
    - Egyptian Law,
    - FIDIC,
    - French Law,
    - German Law,
    - Italian Law,
    - New Zealand Law, and
    - Malaysian law.
- Contractual aspects of soil investigations, and
- questionnaire survey analysis.

Finally, a summary and conclusion of the research, as well as areas for future researches, are presented in Chapter 5.

CHAPTER TWO

LITERATURE REVIEW

2.1. INTRODUCTION

In all construction projects, sufficient information or data is required for a successful design. The purpose of a soil investigation is to provide data concerning the engineering properties of the soil for the proper design and safe construction of a project. Soil investigation is the process by which we obtain relevant properties of soils underlying the site (Abdul Wahid, 2012). The soil investigation phase of any geotechnical design plays a vital role to provide the geotechnical engineer by the most appropriate data to ensure that the design data represent the investigated soil. Inadequate characterization of the subsurface conditions may contribute to either a significantly over designed solution that is not cost-effective, or an under designed, which may lead to potential failures (Goldsworthy *et al*, 2007).

Unforeseen site conditions and the associated geotechnical problems are a major contributor to cost and schedule overruns on the civil engineering projects. In spite of many attempts to deal with these situations by the incorporation of various clauses in contract documents, the problems persist. The best solution is to define the site conditions as early and as accurately as possible so that surprises are minimized (Hoek and Palmer, 1998).

To define the objective of site investigation, British Standards BS 5930 mentioned thatinvestigation of the site is an essential preliminary to the construction of all civil engineering and building works and the objects in making such investigations are as follows:

a) ***Suitability***. To assess the general suitability of the site and environs for the proposed works including, where applicable, the implications of any previous use or contamination of the site.
b) ***Design***. To enable an adequate and economic design to be prepared, including the design of temporary works.
c) ***Construction***. To plan the best method of construction; to foresee and provide against difficulties and delays that may arise during construction due to ground, groundwater and other local conditions; in appropriate cases, to explore sources of indigenous

materials for use in construction; and to select sites for the disposal of waste or surplus materials.

d) ***Effect of changes***. To determine the changes that may arise in the ground and environmental conditions, either naturally or as a result of the works, and the effect of such changes on the works, on adjacent works, and on the environment in general.

e) ***Choice of site***. Where alternatives exist, to advise on the relative suitability of different sites, or different parts of the same site.

f) ***Existing works***. Unless the contrary can be demonstrated, it should be assumed that site investigations are necessary in reporting upon the existing works, and for investigating cases where failure has occurred.

2.2. CHARACTERIZATION OF GROUND CONDITIONS

The characterization of ground conditions might be defined as a process of obtaining geotechnical and geological information in order to determine soil parameters and to model geotechnical or structural engineering design (Arsyad, 2008). Baecher and Christian (2003) divided the characterization of ground conditions into two phases. First is a preliminary investigation or desk study, which involves collecting information about the regional geology and geological history. The second phase is a site investigation designed to obtain data based on detailed measurements of soil properties.

The geological information obtained from the preliminary investigation is data consisting of the stratigraphy of the ground including the thickness and types of each soil or rock layer (Baecher and Christian 2003). This information is used to identify the process of the geological formation of the ground (Arsyad, 2008). Baecher and Christian (2003) classified geological information as qualitative. The other, geotechnical information may be viewed as data sets incorporating the physical and engineering properties of the soil revealed from in situ and/or laboratory tests. This information expresses the mechanical behavior of the soil and is used to predict its response to the proposed loads. These information can be used in foundation system design, including determining the type of foundation and estimating its load capacity and settlement.

A number of research papers illustrated the scope of the characterization of ground conditions. Tomlinson (1969) suggested that the scope of soil investigation correlates to the importance of the structure for which the soil is being characterized, the complexity of the ground, the design of the foundation layout, and the availability of data on existing foundations on similar ground. Furthermore, Rowe (1972) classified the level of importance of projects into three categories. The first category (Group A) is defined as those projects that are considered both important and risky. Their complexity requires extensive soil investigation, as well as sophisticated design necessitating a great deal of subsurface information. These kinds of projects include dams, large underground openings, and major and sensitive projects. The second category (Group B) contains more modest projects that are considered less important or risky than those in Group A. Rowe (1972) has suggested that Group B projects suffer from the difficulty of determining how large the soil investigation should be. The third category (Group C) represents the most routine and lowest risk projects. Such projects require minimal soil investigation.

Bowles (1996) illustrated that generally the characterization of ground conditions might be achieved by several simple activities, such as borehole drilling into the ground, collecting samples for visual inspections and laboratory testing. Clayton *et al*. (1995) added these to preliminary desk studies and air photograph interpretations. In addition, Jaksa*et al*. (2003) indicated that appropriate characterization of ground conditions involves a plan of borehole drilling, material sampling, and laboratory and/or in situ testing. The number, depth and locations of these boreholes, samples, and tests are defined by the geometry of the structure, the loads imposed by the structure and the anticipated subsurface profile.

Baecher and Christian (2003) explained further about the scope of the characterization of ground conditions. They point out that the characterization of ground conditions should be carried out in three steps, as shown in Fig. (2.1). First is reconnaissance that collates a general review of the local and regional geology. The reconnaissance is performed with geological and surveying equipment, air photos, and records of nearby existing construction. Second is a preliminary investigation which confirms the qualitative hypothesis taken from the reconnaissance and establishes a quantitative hypothesis. In this phase, the preliminary investigation is conducted through a limited number of boreholes, field mapping, and geological surveys. Third is a detailed investigation which confirms the quantitative hypothesis. This phase consists of a comprehensive boring program, accurate geometrical information, detailed mapping, and additional geophysical surveys, if necessary.

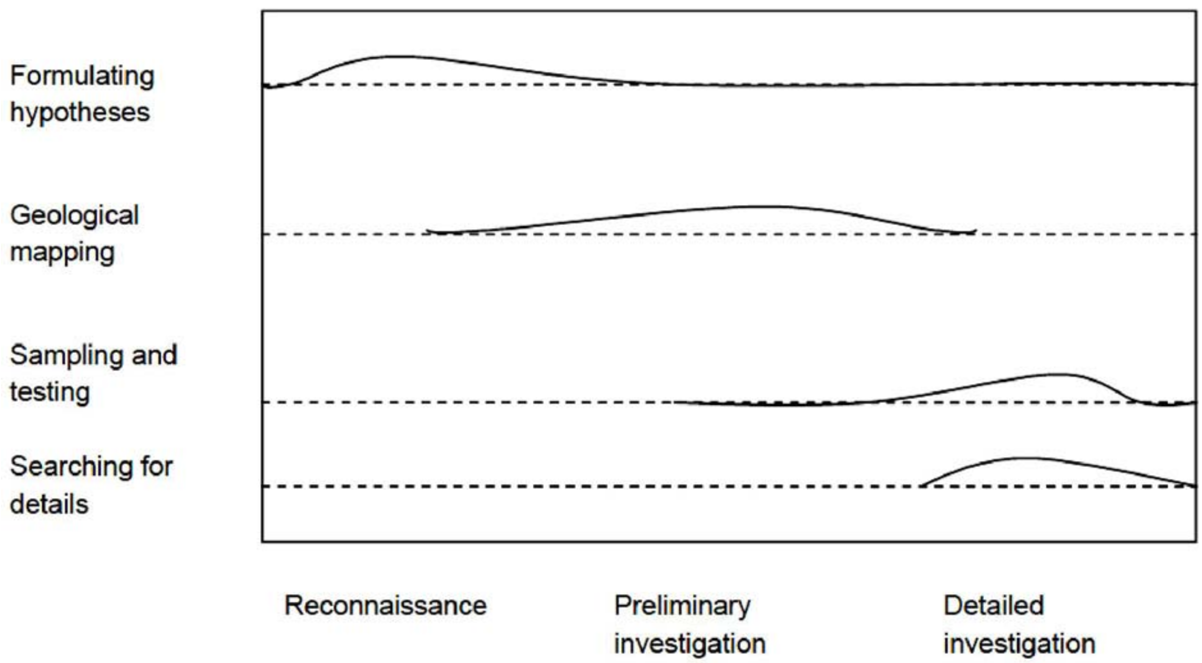


Figure (2.1) Traditional phases of characterization of ground conditions (Baecher and Christian, 2003)

Currently, the scope of the characterization of ground conditions is often determined by the budget and timeline for construction projects (Jaksa*et al*. 2003). These factors must be considered important when deciding the amount and the type of soil investigations (Arsyad, 2008).

2.3. Uncertainty in Geotechnical Engineering

Quantitative measurement of soil properties differentiated the new discipline of soil mechanics in the early 1900s from the engineering of earth works practiced since antiquity. These measurements, however, uncovered a great deal of variability in soil properties, not only from site to site and stratum to stratum, but even within what seemed to be homogeneous deposits. We continue to grapple with this variability in current practice, although new tools of both measurement and analysis are available for doing so (Baecher and Christian 2003).

Vanmarcke (1977a and 1977b) suggested that three main sources of uncertainty exist in the estimation of suitable soil properties. These are due to inherent soil variability, statistical uncertainty due to limited sampling, and measurement uncertainties due to associated geotechnical testing errors. Filippas*et al*. (1988) also categorized uncertainties in a geotechnical system into three main components: Inherent soil variability;Measurement error; and; Transformation model uncertainty.

In addition, Kulhawy (1992) suggested statistical uncertainty, or sampling error, as introduced by Vanmarcke (1977a and 1977b), which results from limited information about the site. This component of uncertainty can be included with measurement error and is minimized through additional sampling (Vanmarcke 1977a and1977b, Phoon*et al*. 1995). Whitman (2000) adopted a simpler explanation, where the uncertainties due to soil variability and random testing errors contribute to data scatter, while the statistical uncertainty and bias in testing error contribute to systematic errors.

Baecher and Christian (2003) mentioned that the inconsistency between the high variability of soil property data and the relatively low rate of failure of prototype structures is usually attributed to two things: spatial averaging and measurement noise. Spatial averaging means that, if one is concerned about average properties within some volume of soil (e.g. average shear strength or total compression), then high spots balance low spots so that the variance of the average goes down as that volume of mobilized soil becomes larger. Averaging reduces uncertainty. Measurement noise means that the variability in soil property data reflects two things: real variability and random errors introduced by the process of measurement. Random errors reduce the precision with which estimates of average soil properties can be made, but they do not affect the in-field variation of actual properties, so the variability apparent in measurements is larger – possibly substantially so – than actual in situ variability.

The following sections identify the three sources of uncertainty defined by Filippas et al. (1988), as well as the statistical uncertainty discussed by Kulhawy (1992).

2.3.1. Inherent soil variability

Unlike many civil engineering media, soils are inherently variable, where properties may be significantly different from one location to another. Even when soils are considered reasonably homogeneous, soil properties exhibit considerable variability (Vanmarcke, 1977a). This variability is due to the complex and varied physical phenomena experienced during their formation (Jaksa, 1995). Variability between soil properties is called spatial variability and has recently been modeled as a random variable (Spry *et al*., 1988).

Phoon and Kulhawy(1996) summarized the variability of soil properties in statistical terms, as shown in Table (2.1).

Table (2.1) Coefficient of variation for some common field measurements (Phoon and Kulhawy, 1996).

Test type	Property	Soil type	Mean	Units	COV (%)*
CPT	q_T	Clay	0.5-2.5	MN/m^2	< 20
	q_c	Clay	0.5-2	MN/m^2	20-40
	q_c	Sand	0.5-30	MN/m^2	20-60
VST	s_u	Clay	5-400	kN/m^2	10-40
SPT	N	Clay and Sand	10-70	blows/ft	25-50
DMT	A reading	Clay	100-450	kN/m^2	10-35
	A reading	Sand	60-1300	kN/m^2	20-50
	B reading	Clay	500-880	kN/m^2	10-35
	B Reading	Sand	350-2400	kN/m^2	20-50
	I_D	Sand	1-8		20-60
	K_D	Sand	2-30		20-60
	E_D	Sand	10-50	MN/m^2	15-65
PMT	P_L	Clay	400-2800	kN/m^2	10-35
	P_L	Sand	1600-3500	kN/m^2	20-50
	E_{PMT}	Sand	5-15	MN/m^2	15-65
Lab Index	w_n	Clay and silt	13-100	%	8-30
	W_L	Clay and silt	30-90	%	6-30
	W_P	Clay and silt	15-15	%	6-30
	PI	Clay and silt	10-40	%	_a
	LI	Clay and silt	10	%	_a
	γ, γ_d	Clay and silt	13-20	kN/m^3	< 10
	D_r	Sand	30-70	%	10-40; 50-70[b]

Notes:-

a - COV = (3-12%)/mean.

b - The first range of variables gives the total variability for the direct method of determination, and the second range of values gives the total variability for the indirect determination using SPT values.

Baecher and Christian (2003) mentioned that the important thing to note in Table (2.1)is how large are the reported coefficients of variations of soil property measurements.

2.3.2. Statistical Uncertainty

The statistical uncertainties associated with a geotechnical model are a result of limited sampling that may not provide an accurate representation of the underlying conditions (Goldsworthy, 2006). Filippas*et al*. (1988) defined the statistical uncertainty for a set of uncorrelated samples as the variance in the estimate of the mean. In this case, as suggested by DeGroot (1986), the central limit theorem was used, with a formulation given by:

$$Var(\mu) = \frac{\sigma^2}{n}$$

WhereVar(μ)is the variance of the sample mean;

σ^2 is the sample standard deviation;

n is the number of samples.

Baecher and Christian (2003) suggested that the variance of the sample mean should consider the location of the sampling. Therefore they proposed that the variance of the sample mean be correlated to spatial sampling as shown in following Equation:

$$Var(\mu) = \frac{\sigma^2}{n}\frac{n_t - n}{n_t}$$

Where n_t is the total population size

In comparison to the values shown in above Equation the estimation variance for systematic (Cochran 1977) and stratified random sampling (Thompson 2002) is respectively given by:

$$\text{Var}(\mu) = \frac{1}{n}\left(\frac{n_t - n}{n_t}\right)\left(\frac{\sum (x_i - \mu)^2}{n-1}\right)$$

and

$$\text{Var}(\mu) = \sum_i e_i^2 \frac{\sigma_i^2}{n_i}(1 - f_i)$$

Where x_i is the sampled value; e_i is the size of the *i*th element divided by the total population size; $\sigma^2 i$, is the standard deviation within the*i*th element;n_i is the number of samples taken from the *i*th element and f_i is defined as n_i / n_t.

Jaksa (1995) has also investigated the variability of soil properties using over 200 CPT data. The result showed that the COV of $q_c$is about 60%.

2.3.3. Measurement error

Measurement uncertainty arises from inaccurate measurement of soil properties. This uncertainty is incorporated in the characterization of the ground and in parameters and models (Baecher and Christian 2003).

Measurement uncertainty can be divided into two categories: systematic and random errors (Lee *et al*. 1983; Orchant*et al*. 1988). Systematic errors are the consistent underestimation or overestimation of soil properties (Jaksa 1995). Systematic errors are caused by equipment and procedural errors occurring during the measurement of soil properties (Orchant*et al*. 1988). Random errors, on the other hand, are the variation of test results which is not directly related to soil variability, equipment and procedural errors (Jaksa 1995). These errors generally have zero mean, influencing the test results of soil properties equally, both above and below the mean (Baecher 1979; Snedecor and Cochran 1980).

Orchant*et al*. (1988) introduced the following relationship to quantify measurement errors.

$$\sigma_m{}^2 = \sigma_e{}^2 + \sigma_p{}^2 + \sigma_r{}^2$$

where σ_m^2 is total variance of measurement;
σ_e^2 is the variance of equipment errors;
σ_p^2 is the variance of procedural errors; and
σ_r^2 is the variance of random errors.

The equation above does not, however, deal with soil variability. Therefore, Jaksa (1995) suggests that the formula of quantification of measurement errors could be improved by using the variance of soil variabilityσ_{sv}^2as described by Equation 2-13:

$$\sigma_m{}^2 = \sigma_e{}^2 + \sigma_p{}^2 + \sigma_r{}^2 + \sigma_{sv}{}^2$$

Many researchers have investigated measurement errors of in-situ tests used in characterizing the ground conditions. The results of these measurement errors have been summarized by Phoon and Kulhawy (1999b) as shown in Table 2.2.

Table (2.2) Measurement error of geotechnical tests (Phoon and Kulhawy, 1999b and Goldsworthy, 2006)

Test type	Measurement errors (in coefficient of variation %)					
	Equipment	Procedure	Random	Total	Range	Researchers
Cone Penetration Test (CPT)	3	5	5-10	7-10	7-12	Orchant*et al.* 1988
					5-40	Phoon&Kulhawy 1999b
Standard Penetration Test (SPT)	3-75	5-75	12-15	14-100	27-85	Lee *et al.* 1983
					25-50	Phoon&Kulhawy 1999b
Dilatometer Test (DMT)	5	5	8	—	11	Orchant*et al.* 1988

2.3.4. Transformation model uncertainty

Transformation model error is equivalent to knowledge uncertainty (Goldsworthy 2006). The results of common geotechnical in situ tests do not typically provide applicable soil properties that are useful for design relationships (Phoon and Kulhawy1999a). Rather, the raw test results are processed using a transformation model into a suitable design parameter. Such models are obtained empirically through back substitution or calibration. Accordingly, a degree of uncertainty is added to the estimation of the design parameter. Phoon and Kulhawy (1999a) further stated that uncertainty still exists if the transformation is based on a theoretical relationship because of idealizations and simplifications in the theory. Therefore, it is important to consider the uncertainties due to transformation model error.

2.4. PREVIOUS WORK ON EFFECT OF INADEQUATE SOIL INVESTIGATIONS

Soil investigation is normally required and carried out prior to the commencement of design of a construction project. Due to lack of or inadequacy of guide/code requirement regarding the extent as well as quality of soil investigation work, geotechnical failures often occurred. These failures sometime led to catastrophic disaster and imposed serious threat to public safety (Moh, 2004).

The purpose of a construction geotechnical investigation is to provide soil property data for the design and implementation of a project. With this information a safe, economic foundation may be designed. Inadequate geotechnical investigations are currently the first source of costly, overdesigned foundation, project delays, disputes, claims, and project cost overruns. This is a growing and expensive problem to owners, designers, and the construction industry. There is a link between lower construction costs and good geotechnical investigations (Temple and Stukhart, 1987)

Jaksa*et al.* (2005) suggested that the soil investigations that inadequately quantify the variability of the ground can result in three possible cost outcomes:

a) The foundation is underdesigned as a result on an overly optimistic geotechnical model, and hence fails to comply with the design criteria, which can ultimately lead to some level of structural distress.

b) The foundation is overdesigned as a consequence of a pessimistic geotechnical model and/or inherent conservatism in the design process.

c) Unforeseen conditions require substantial changes to the foundation system, which also result in construction delays.

As explained by the Institution of Civil Engineers (1991), over the last 30 years the scope of soil investigations has often been governed by a desire achieve minimum cost and against a background of time constraints. Clients or designers prefer to allocate a limited amount of their budgets to soil investigation, and then design the foundations conservatively to overcome inadequate data from limited investigations (Bowles, 1996). Moreover, generally, geotechnical engineers use more intuitive methods of engineering judgment based on extensive experience with site conditions rather than analysis based on strategy and inference (Baecher and Christian, 2003).

As a result, the geotechnical data obtained from limited characterization of ground conditions can be both inadequate and/or inappropriate. This situation can lead to foundation failure and a high level of financial and technical risk (Institution of Civil Engineers, 1991; Littlejohn *et al*., 1994; National Research Council, 1984; Temple and Stukhart, 1987). Inadequate soil investigation is one of main reasons for construction cost overruns and constructions delays, as well as potential injury to the structure's occupants (Institution of Civil Engineers, 1991; National Research Council, 1984).

Goldsworthy *et al*. (2007) defined the financial risk as the total cost, which includes costs associated with undertaking the soil investigation, constructing the foundation and superstructure, and any works required to rehabilitate a foundation failure, and defined the total cost of the foundation as the costs associated with the soil investigation, construction of the foundation and any potential rehabilitation costs associated with a foundation failure.

A report by the National Economic Development Office (NEDO, 1988) considered that although building sites were often difficult in terms of legal and planning requirements, as well as having demands and constraints imposed on the building operation by conditions on the ground, the most frequent explanation of overruns and long delays (more than 10 weeks) was unforeseen obstacles in the ground.

Several studies have been published over the last 30 years or so that clearly demonstrated that, in civil engineering and building projects, the largest element of financial and technical risk usually lies in the ground (National Research Council, 1984, Institution of Civil Engineers, 1991, Littlejohn *et al*., 1994, Whyte, 1995). Indeed, structural foundation failure can often be attributed to inadequate and/or inappropriate soil investigations (Nordlund and Deere, 1970, ASFE, 1996). These international studies have demonstrated that most geotechnical investigations are inadequate because, in the vast majority of cases, too few resources are committed to the investigation and, as a result, its scope is inadequate. Expenditure on geotechnical investigations varies considerably, sometimes as low as between 0.025% and 0.3% of the total project cost. In addition, these studies have demonstrated that low levels of investigation result in large uncertainties, which often result in unforeseen additional construction and/or repair costs. Furthermore, inadequate geotechnical investigations usually force the geotechnical engineer to reduce the risk of failure by overdesigning the foundation, thereby increasing the cost of the project (Jaksa*et al.,* 2003).

The cost of soil investigations in relation to the total project cost is small. Typical values in buildings projects are between 0.05% and 0.20% of total project cost, or between 0.5% and 2.0% of foundations cost. While the typical values are between 0.20% and 1.50% of total project cost or between 1.0% and 5.0% of foundations cost in roads projects. Soil investigations should be continued until the ground conditions are known well enough for work to precede safely. Although a doubling in soil investigations costs can add 1.0% to the total project cost. Unforeseen ground conditions can, and often do, raise the costs by 10% or more (Paul *et al.,* 2002).

It is well understood that a detailed soil investigation, consisting of many samples and refined testing methods, yields a better representation of the underlying soil conditions. However, is it really worth spending additional money to retrieve additional samples, or use better testing methods? Until now, this decision has typically been made based on project budget and time restrictions, and at the discretion of the geotechnical engineer (Jaksa*et al*., 2005).

The inherent site conditions of a project affect the speed of delivery (Frimpong et al., 2003). This is often due to a lack of or poor investigation of site ground conditions to obtain data regarding site soil conditions. Site conditions refer to the features on a site, whether there are existing structures or not; the condition of the subsoil; the firmness of the earth beneath the surface; the distance of the water table to the surface; underground service ducts and similar features. The research of Frimpong*et al.* (2003) found that ground problems and unexpected geological conditions contribute to delays. Many unforeseen difficulties can be encountered during production due to lack of testing and investigation of a site soil. This may lead to delay in the delivery of projects (Blismas*et al.,* 2004).

Unfortunately, geotechnical engineers have at their disposal limited guidance when deciding upon a scope of a soil investigation. Almost exclusively, the scope of such investigations is not governed by what is needed to characterize appropriately the subsurface conditions but, rather, how much the client is willing to spend on a geotechnical investigation. What is urgently needed is a series of guidelines that link the scope of a soil investigation with the probability that the foundation will be underdesigned – resulting in some form of failure, or be overdesigned – resulting in more funds being spent on the foundation than would have otherwise been necessary had a more appropriate soil investigation been carried out (Jaksa*et al.,* 2003).

Despite the level of sophistication available for the determination of risk and uncertainty associated with ground work operations, a review of 5000 industrial building projects by the National Economic Development Office in the UK (NEDO, 1983) showed that 37% of the projects suffered delays due to ground related problems. In another report by NEDO, 1988, 8000 commercial buildings were examined, 50% of the samples were found to have suffered unforeseen ground difficulties. The financial scale of the problem was confirmed by the National Audit Office (1994), in a report that recorded 210 premature failures during construction works, and that geotechnical failures were a major concern. Alhalby and Whyte's (1994) research concluded that "90% of risk to projects originates from unforeseen ground conditions which could often have been avoided by adequate and full soil investigation".

CPD (2012) mentioned inadequate soil investigation as one of the most important sources for claims against engineers. In the US, an analysis of 89 underground projects concluded that, in more than 85% of cases, the level of geotechnical investigation was too low for adequate characterization of site conditions, leading to claims and cost overruns (National Research Council 1984). It is clear that over the last 30 years geotechnical investigation prices have been driven down, with the scope often being governed by minimum cost and time of completion (Institution of Civil Engineers 1991). As a consequence, the Institution of Civil Engineers concluded that: "*You pay for a site investigation whether you have one or not*."

There are several factors which strongly influence the costs of geotechnical investigations: (1) Foundation type; (2) degree of site soil variability; (3) building purpose; (4) building loads/configuration; and (5) prior knowledge (if any) of site subsurface conditions. These factors tend to reduce the reliability of the cost estimation techniques. They also influence the expense of the soils study far more than just the cost of construction and they are site peculiar characteristics as well. Foundation complexity coupled with highly variable site soil conditions contribute the most to increases in soil study costs. Therefore owners and designers cannot rely on mathematical models to help estimate and/or control these costs (Temple and Stukhart, 1987).

A number of research papers quantified the effect of inadequate soil investigations on the construction projects. Goldsworthy *et al.* (2004) studied the effect of soil investigations for a foundation consists of 4 equally loaded pad footings, and suggested that the time and cost constraints, as well as the judgment and experience of the consulting geotechnical engineer, have traditionally governed the scope of soil investigations. Analyses have been undertaken to investigate the performance of various soil investigation schemes with respect to the cost of the resulting pad foundation system and the probability of failure. Penalty costs are attributed to foundation designs that experience excessive settlement to enable direct comparisons with foundation designs that conform to the design criteria. This design is compared with a design based on information obtained from a simulated soil investigation, representing a traditional design procedure, which is heavily influenced by the quality and quantity of information obtained from the soil investigation and provides the basis for the analyses presented. The framework adopted in is proposed by Jaksa et al. (2003) summarized in flowchart form in Fig.(2.2).

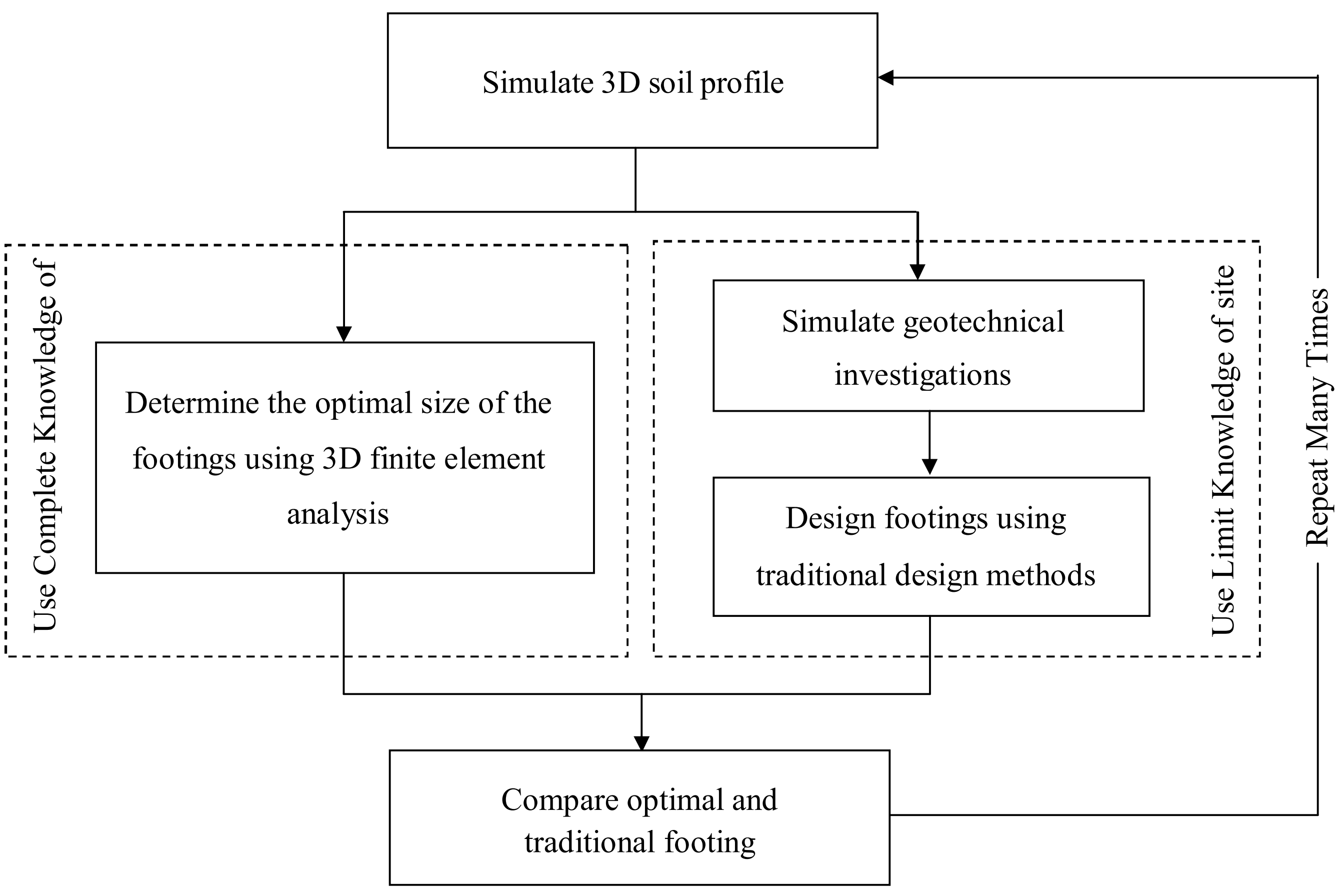


Figure (2.2) Framework adopted in the analysis (Goldsworthy et al., 2004)

To determine the potential failure cost, Goldsworthy et al. (2004) divided the failure severity scheme into three categories; minor retrofit; major retrofit and demolish & rebuild. The rehabilitation costs for each failure severity have also been determined using unit rates suggested by Rawlinsons (2002). Table (2.3) summarizes the rates adopted for each of the failure severity categories, while Fig. (2.3) graphically presents the penalty cost ratio (defined as the retrofit cost divided by the total building cost) for varying building heights.

Table (2.3) Foundations failures categories (Goldsworthy et al. 2004)

Failure Severity	Failure Description	Unit Rate Description (Rawlinsons, 2002)
Minor	Some cracking evident from excessive settlement – requires patching and repainting	Minor refurbishment works divided by 2 (not include plumbing etc…)
Major	Major cracking and structural failures – requires significant patching, structural retrofitting and foundation underpinning	Major refurbishment works + Foundation underpinning
Demolish & Rebuild	Building can no longer be used for intended purpose – requires complete demolition and rebuild	Demolish costs + Rebuild costs

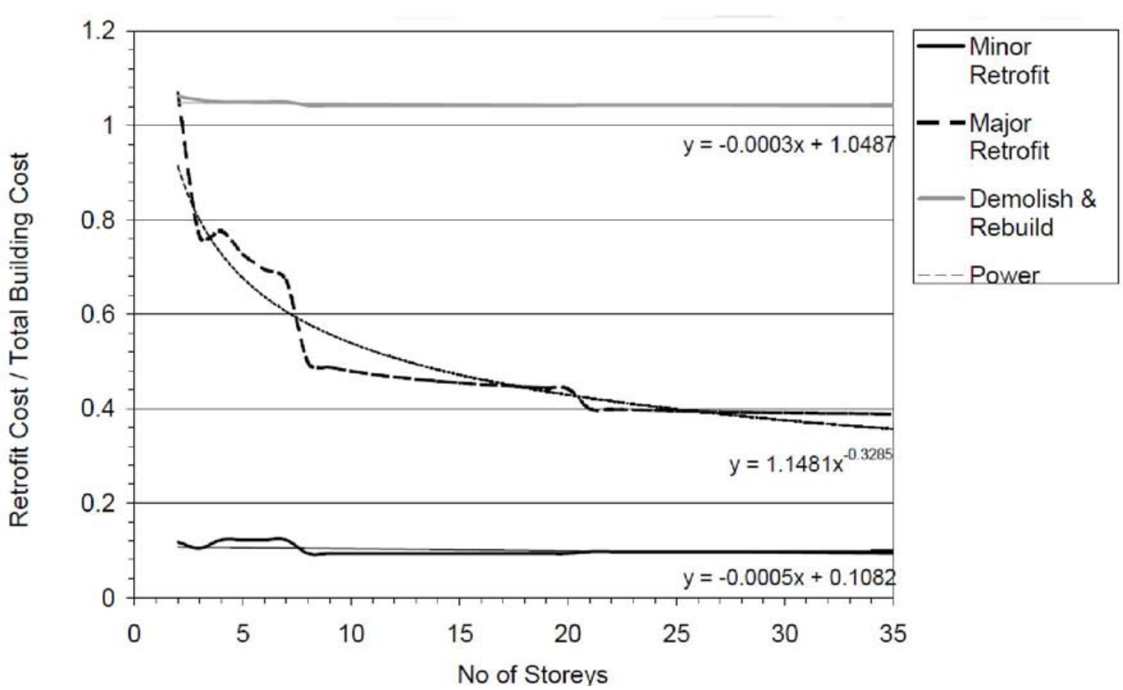
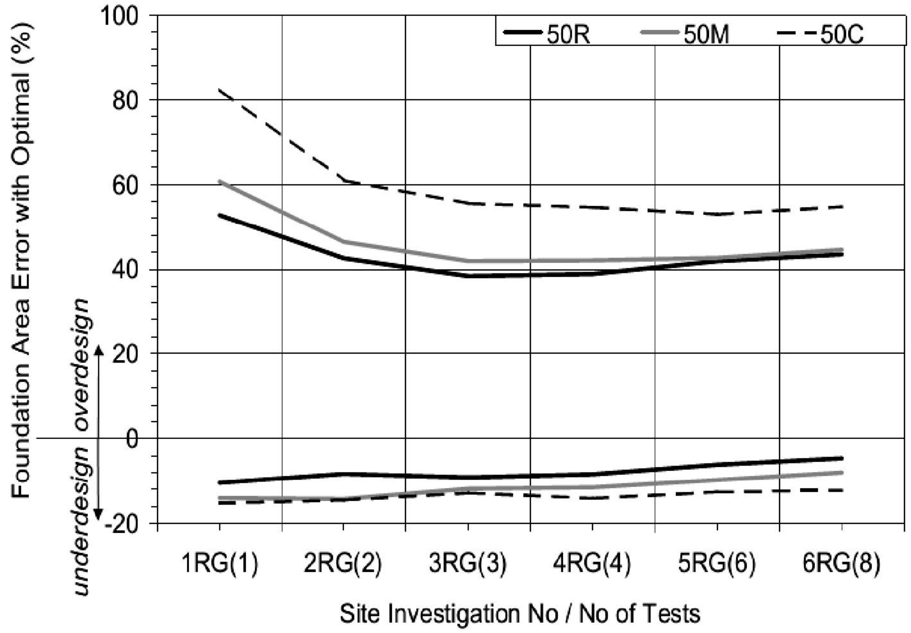


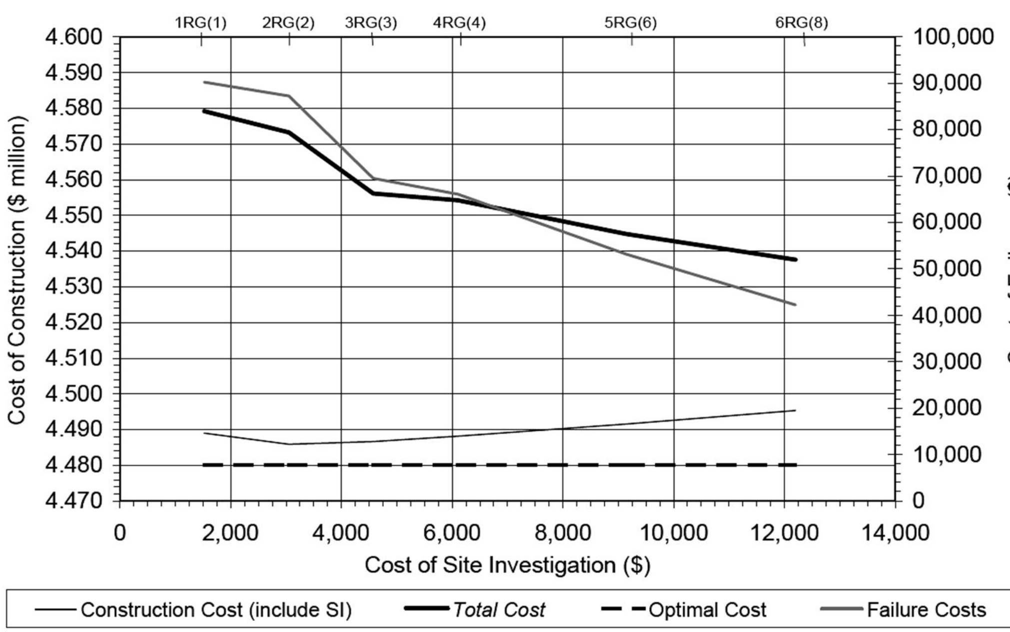
Figure (2.3) Cost ratio of minor retrofit, major retrofit and demolish & rebuild for varying number of building storeys (Goldsworthy et al. 2004)

The model adopted by Goldsworthy et al. (2004) to simulate a foundation design, was introduced by Jaksaet al. (2003), involves simulating 3-dimensional soil profiles to enable all soil properties to be known at all locations. The soil types are distinguished the coefficient of variation, COV (standard deviation/mean) andscale of fluctuation. The letters R, M and C after the COV number represent a random, medium or continuous profile, respectively. The random, medium or continuous nature of the profile is determined by the scale of fluctuation, where a small scale of fluctuation represents a randomly varying field, while a larger scale of fluctuation represents a continuously varying profile, that is, where properties vary more slowly with respect to distance.The simulated soil profiles are generated to conform to random field theory (Vanmarcke, 1984), where the dominant statistics are the mean, variance and scale of fluctuation (SOF)(Where SOF is measure of the distance of separation at which two samples are considered reasonably correlated (Vanmarcke, 1984)). Using the knowledge of the soil profile, an optimal design is determined using a 3-dimensional finite element analysis. The results illustrate a decreasing trend of overdesign probability, underdesign probability, and total foundation cost for an increasing site investigation scope as shown in the Fig. (2.4). The results also show that the cost of a foundation, excluding the penalty cost of failure, designed using an increased amount of knowledge regarding the site, does not always result in a less expensive foundation. However, all results suggest that a site investigation scheme with limited testing will result in a more expensive foundation, when the cost of possible foundation failure is included.

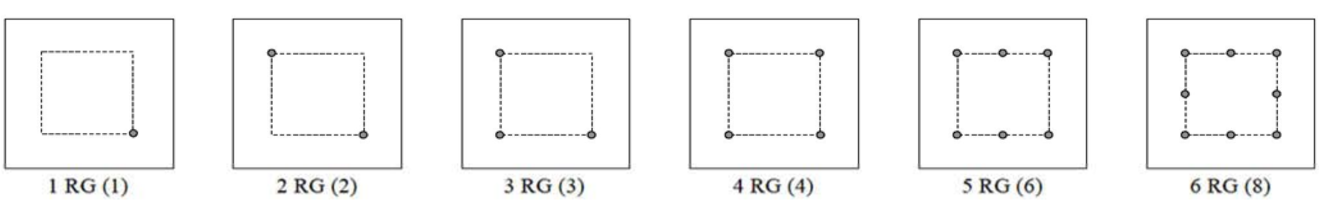
AS shown in the Fig. (2.4), Goldsworthy *et al.* (2004) reached to a conclusion that the risk of an over-designed foundations, under-designed foundations, andfoundation failure is heavily dependent on the quantity and quality of information obtained from a geotechnical site investigation aimed at characterizing the underlying soil conditions. This research has shown that by increasing the scope of the site investigation, the risk of foundation failure is significantly reduced, potentially saving clients and consultants large amounts of money. It has been demonstrated that, for the loading and soil conditions considered, a slight increase of expenditure at the site investigation stage may result in a potential saving in the expenditure amount as.



(a) Foundation design area difference with optimal design for soil profiles of (COV = 50%)



(b) Effect of number of tests on the construction and failure costs



(c) Site investigation schemes

Figure (2.4) Effect of number of tests on foundation error, and on the construction and failure costs for COV= 50% (Goldsworthy *et al.,* 2004)

Goldsworthy *et al*. (2007) also studied the effect of site investigations for 5 storeys structure with foundation consists of 9 pad footings 8.0m separate on different soil types. Results shown in Fig. (2.5) illustrated the influence of increased sampling on the construction cost for different soil types. In general, these results indicate that the construction cost reduce as sampling increases. This typically infers that the conservatism in the foundation design is reduced as additional sampling is undertaken.

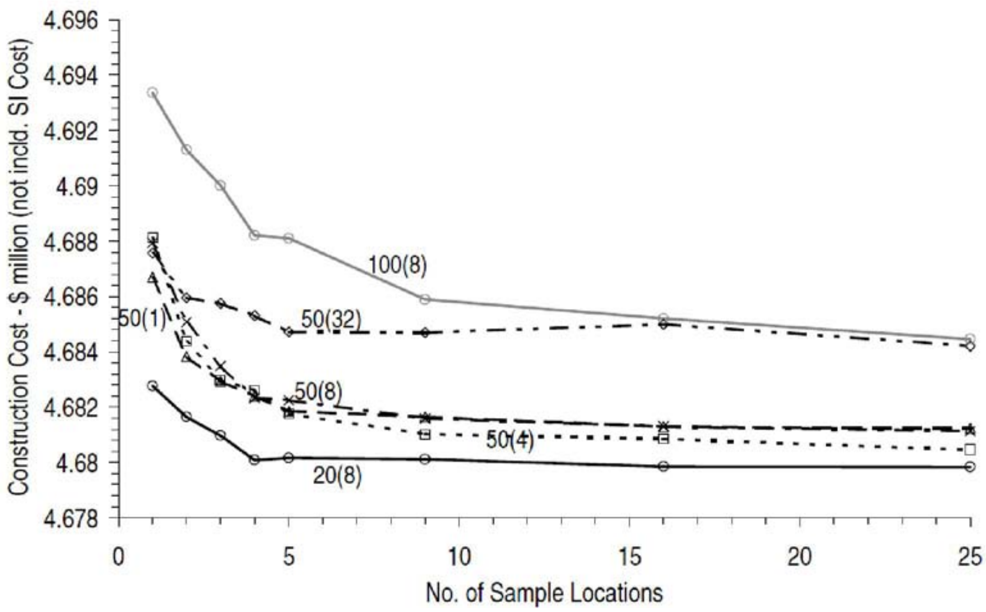


Figure (2.5) Effect of number of tests on the construction cost for different soil types (Goldsworthy *et al.,* 2007)

Results also demonstrated the impact of additional site investigation expenditure on the total cost for different soil types (Fig., 2.6). The results shown in Fig.(2.6) suggest that the rehabilitation costs have a large influence on the total cost. Therefore, foundation designs should be targeted towards minimizing the rehabilitation costs, even if this infers a larger construction cost.

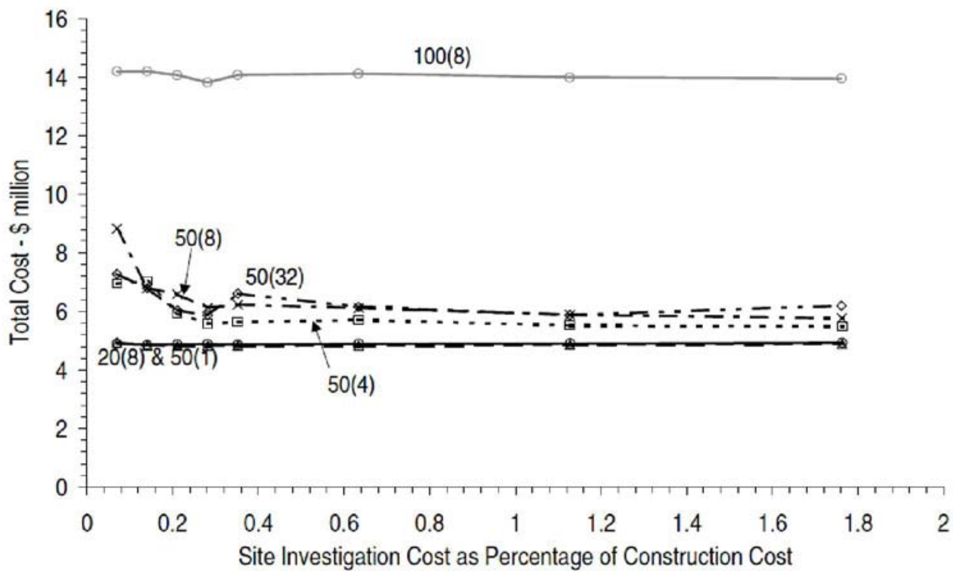
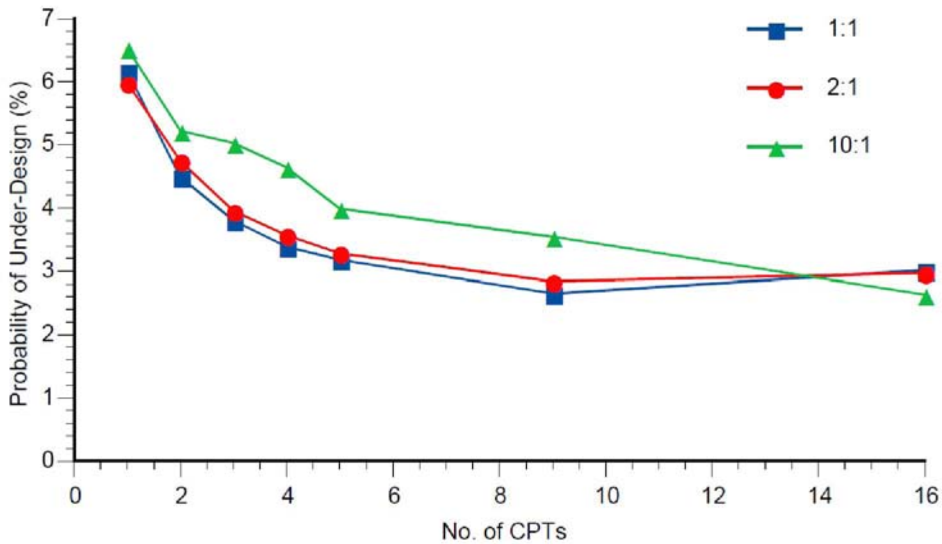


Figure (2.6) Effect of increasing site investigation expenditures on the construction cost for different soil types (Goldsworthy *et al.* 2007)

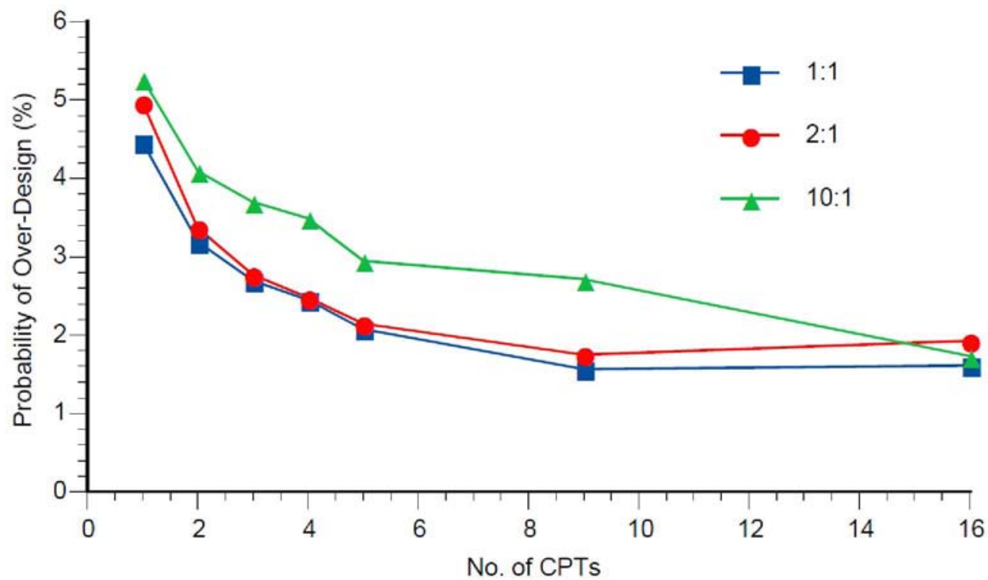
Goldsworthy *et al*. (2007) reached to a conclusion that the financial risk of a foundation design is considerably reduced by increased site investigation expenditure. However, there appears to be optimal site investigation expenditure, where the total cost of the foundation design is a minimum. Furthermore, results have shown that different methods of characterization lead to varying degrees of risk exposure. Therefore, it is not only the extent of the investigation that needs careful consideration, but also the type of geotechnical test used, and the method used to select characteristic values. The form of investigation, including the type of geotechnical test used and the means of selecting a characteristic value are both shown to have an influence on the risk of the foundation design. It should be noted that the results presented in this paper are based on a single layer, statistically homogeneous soil, which is free from defects or other irregularities. In reality, the ground is typically highly variable and consists of complex layering.

Arsyad, (2008) also studied the effect of soil investigations for a building founded on piles. The foundation system was 50m x 50m raft foundation rested on 9 piles 12.50m separate on different soil types and different types of tests. Soil types are distinguished by the SOF in parentheses (e.g. 2:1 represents a SOF of 2 m in the horizontal direction and a SOF of 1 m in the vertical direction). The framework adopted in the analyses is proposed by Jaksa*et al.*

(2003) (Fig., 2.2). The results in the Fig. (2.7) for CPT based,soil investigations shows that the proportions of overdesign and underdesign generally decrease with a greater number of tests.



(a): Effect of increasing soil investigation tests on the probability of under-design of pile foundations, for different soil types



(b): Effect of increasing soil investigation tests on the probability of over-design of pile foundations, for different soil types

Figure (2.7) Effect of increasing soil investigation tests on the probability of under-design and over-design of pile foundations, for different soil types (Arsyad, 2008)

Arsyad, (2008) reached to a conclusion that an increased number of CPTs in soil investigations have a significant impact on the reliability of the design of pile foundations. The results indicate that a more intensive sampling effort results in a lower probability of under and over design. The number of piles in the simulation has significant impact on the probability of under or over design, as well as the averaging methods.

2.5. RESPONSIBILITYOF THESOIL INVESTIGATION

Halligan et al. (1987) stated that a proper and economic design of a structure requires an examination of local site conditions, key utilities, and structural features. Increasingly, however, owners fearful of assuming unwanted liability are disclaiming or excluding any reference to site conditions from construction contract documents. These owners fear contractors' claims asserting that reports on site conditions led to unreasonable expectations about the work or contributed to unsafe working conditions. These disclaimers and limited studies of the site are intended to relieve owners of responsibility for unforeseen site conditions and their consequential effects. However, questions over site conditions, particularly those unforeseen by the parties, continue to persist.

Halligan et al. (1987) mentioned that, in most cases, owners attempt to use the construction contract to apportion responsibility for unforeseen conditions to achieve a certain cost objective. Typically, owners wish to minimize total project costs or to minimize variance of final cost from the bid. The ultimate question, then, is whether or not the contractual approach is effective in meeting these objectives. When drafting contract language to minimize costs, the owner is ultimately weighing the economics of bearing the risks for unforeseen conditions versus having the contractor assume these risks. In this effort, there are at least three basic approaches that may be taken: (1) The responsibility can be wholly placed on the contractor; (2) responsibility can be retained by the owner; or (3) responsibility can be somehow shared between the two.

1) **Contractor Assumes All Responsibility** - When the responsibility for unforeseen site conditions is to be placed on the contractor, an owner will typically employ a Site Information Disclaimer and Site Investigation clause. The owner and its site information are contractually isolated from the construction process. To avoid charges of fraud, the

owner must at least make the information available, but the responsibility for its use is assigned to the contractor. The risks, responsibility, and financial burden of unexpected site conditions have been transferred to the contractor, and such conditions and their effects on the project are theoretically no longer a concern of the owner.

This is the traditional and most common allocation of the responsibility for unexpected site conditions.

2) **Owner Assumption of Risks -** When the responsibility for unexpected site conditions is to be retained by the owner, contractors may rely on the geologic and other information included in the contract, and the owner assumes responsibility for unforeseen conditions and their consequential effects. In principle, the owner may be liable for reasonable interpretations of the site information and contract documents, and conditions not foreseeable given the general geologic regime and type of work involved. Furthermore, the owner may be liable for both the direct and consequential impact of the unforeseen conditions on the contractor's costs and schedule.

3) **Shared Responsibility -** There are a wide range of risk-sharing contractual agreements. Examples may be studied, but the choice is virtually unlimited. The agreement might include a clause that limits the owner's responsibility to direct costs. Another alternative is to state explicitly the types and ranges of conditions for which the owner or the contractor are to be responsible. If this specialized form of clause is used, it should reflect the unique aspects of the project for which it is to be used. However, the drafting of a unique clause removes or limits the precedent of prior practices and judicial interpretation, and this may substantially distort the risk allocation.

Temple and Stukhart (1987) suggested that there are two ways to obtain geotechnical investigations:-

a) The owner may directly contract with a geotechnical firm to conduct the study, later transferring the data to a separate architect/engineer (A/E) for design purposes (Carter, 1987,Schoumacher, 1982). Here the owner has maximum control over the cost of the study and, initially, this may appear to be most desirable from the owner's viewpoint. Unfortunately, this sometimes means that the owner economizes on the scope of the investigation, or fails to have one conducted at all. Also, due to a lack of project definition, many owners cannot give adequate guidance to the soils consultant, thereby receiving an insufficient or misleading study.

b) The owner may contract with a design firm who may subcontract with a geotechnical engineer or, if the firm is large enough, it uses in-house soils specialists to provide subsurface data (Carter, 1987, Schoumacher, 1982). From an engineering viewpoint, A/E control over the investigation is preferable because the A/E can guide the study based on his perception of the data required to properly design the project foundation. However, owner pressure or A/E misassumptions (in knowledge of the site or in foundation design) may result in a poorly funded study or none at all (Dallaire, 1976, Gedney, 1974, Thompson and Tannenbaum, 1977).

2.6. SUMMARY

The treatment of the literature in this chapter has indicated that the scope of soil investigation must be studied and planned correctly. In geotechnical engineering practice, uncertainties of the field measurement are due to three main sources; inherent soil variability, measurement error and transformation model uncertainty or statistical uncertainty. Measurement uncertainty is divided into two categories: systematic and random errors.The best method to reducing this uncertainty is by making a proper soil investigation.

Inadequacy of asoil investigation may lead to insufficient knowledge of ground conditions. Unforeseen geotechnical site conditions may appear and this may cause engineering and financial problems on various construction projects. Insufficient geotechnical investigation is one of the most effective sources of costly, overdesigned foundation, project delays, disputes, claims, and project cost overruns. This is a common problem to owners, designers, and the construction industry.

There are a certain number of tests that make the site conditions well-known, but this number is variable according to the site and loads conditions. The optimum number is identified by the optimal soil investigation expenditure, which leads to the least financial risk, and where additional sampling becomes redundant. It is hard to define a certain number for the cost of soil investigation, but it could be said that the cost of soil investigations in relation to the total project cost is small. Typical values in buildings projects are 0.05% and 0.20% of total project cost, or 0.5% and 2.0% of foundations cost and the typical values in roads are between 0.20% and 1.50% of total project cost,or 1.0% and 5.0% of foundations cost(Paul *et al.,* 2002). If the soil has a major variation in its interpretation the soil investigations should be continued until the ground conditions are known well enough for work to proceed safely.

CHAPTER THREE

DATA COLLECTION AND ANALYSIS

3.1. INTRODUCTION

From the previous literature review it could be said that the soil investigation scope affects the total cost of construction. Inadequacy of the soil investigation may lead to increasing of the project total cost, or may cause an increase of the project duration which leads also to an increase in the project total cost.This chapter illustrates the case studies that have been chosen. In this chapter, the collected data has been summarized to give an idea about each case study description, original soil investigations, problems, causes, and corrective action, then, studying the effect of inadequate soil investigation on cost and duration of projects.

3.2. METHODOLOGY

The study is conducted through the following sequence:

- The treatment of literature survey in chapter two showed that soil investigation scope has a major effect on a project cost, especially the foundation cost, consequently the whole project cost. This is a result of large uncertainties associated with traditional soil investigation process, and potential financial and time costs.
- Data have been collected to study the effect of the inadequacy of the soil investigation. Thedata collected from six case studies with different problems due to inadequate or inappropriate soil investigation.
- Data analysis performed to evaluate the consequences of inadequate soil investigation. The analysis is conducted as following:

a) Overview the project original soil investigations to determine the soil investigation scope.

b) Overview the original soil investigations cost.

c) Comparing original soil investigation as a percentage of the total cost with the typical percentage according to literature and/or codes requirements.

d) Evaluating the problems that occurred in the projects due to inadequate soil investigations.

e) Computing or (estimating if not available) the rehabilitation cost for these problems.

f) Evaluating the soil investigation needed to reach the acceptable knowledge for the site conditions.

g) Comparing the cost of extra soil investigations with the rehabilitation cost.

h) Overview the original project schedule, and determine if any delays occurs due to soil problems.

- Studying the contractual and legal aspects of soil investigation including studying different laws, and measuring the engineers' opinion of how this problem can be handled by a questionnaire survey.

3.3. CASE STUDIES DESCRIPTION AND ANALYSIS

To achieve the research goal, six cases have been chosen. Each case study has a different problem causes, consequences and rehabilitation, and all of them are due to inadequate or inappropriate soil investigation. The cases are as follow.

3.3.1. Media production city

3.3.1.1. Project description

The project occupies a wide area in the 6thof October City, at about 25 Km to the west of Cairo City, Egypt. The Media Production City project is aimed at constructing one of the largest studios for cinema, television, recreational and tourism centers in the world. This selected phase of the project occupies 680m x 680m in plan. About one sixth of this area will be occupied with buildings forming almost a triangular shape. The complex comprises 114 cinematographic, television and video shooting studios, where state-of-the-art technology is to be used. Structures incorporated in this phase contain administration buildings, studio buildings, workshops, power plant, water tanks, polyester workshops, and entrance gate.

These structures vary in height from approximately 6.0m to 40.0m measured from the ground floor slab to the roof. The contract for constructing and equipping the International Studio Complex was signed in January 1997. The project was expected to be completed within three years, at a total cost of 340 million US dollar, including costs of infrastructure, construction, equipment and appliances.

3.3.1.2. Original soil investigations

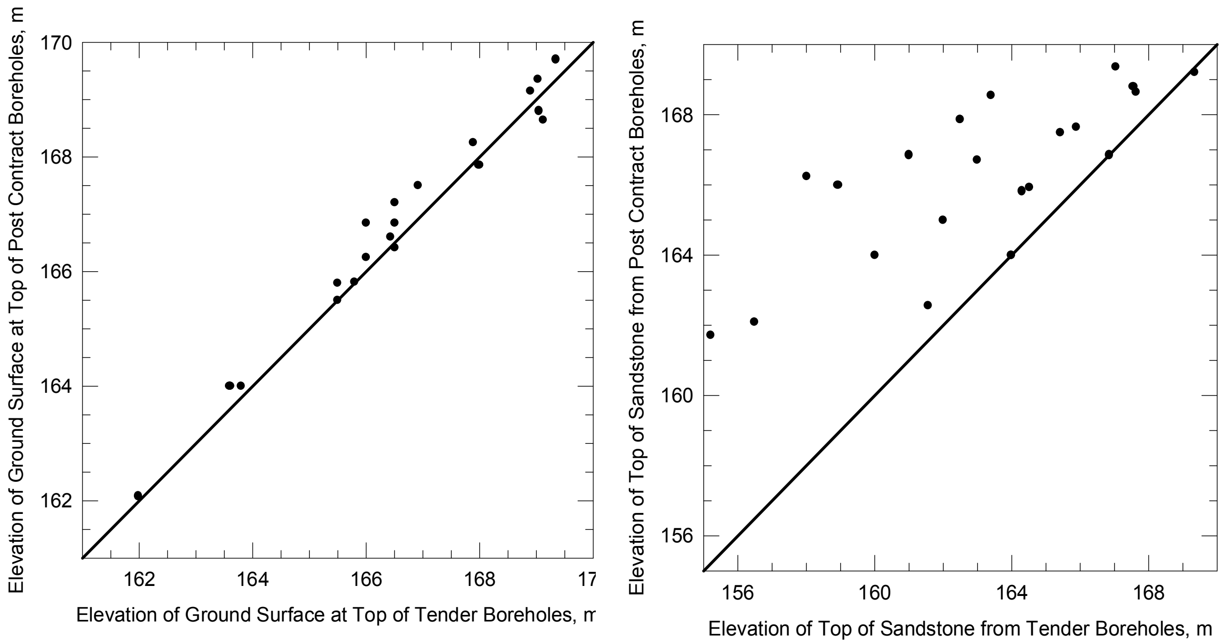
The tender geotechnical investigations report was prepared in 1990. The report consisted of eighty four (84) boreholes up to 10.0m in depth from the ground surface. The tender report indicated a presence of sand or cemented sand or cemented silty sand above layer of sandstone. The top of the sandstone layer appeared at ground surface in 25 boreholes (about 30% of the boreholes). The tender geotechnical investigation contains bulk unit weight and confined compressionstrength of the rock samples. According to these data, the sandstone intact samples can be classified as Moderately Weak.

3.3.1.3. Problem

Based on tender soil investigation, the contractor submitted his proposal for the project excavation. The problem shows during excavation. It was that the sandstone layer was encountered at a shallower depth than the reported depth in the tender geotechnical investigations report, and also stronger than the reported strength. This change in the quantity and strength of the rock layer leads to a higher cost and a longer time for the excavation. This problem caused a disputation between the contractor and the owner, acompromise has proposed after making new soil investigation by a third party.

3.3.1.4. Causes

Original soil investigation shows that the sandstone layer is wrongly located deeper than the layer's actual depth, which means that the excavation was almost on sandActually the excavation was mainly in the sandstone layer, which means that the excavation costs more than estimated and needslonger timethan scheduled. Figure (3.1) shows the differencebetween the ground surface elevation and the sandstone layer top surface elevation for the tender soil investigation boreholes and post-tender soil investigation boreholes.



(a) (b)

Figure (3.1) Ground surface and sandstone layer top surface elevations for the tender and post-tender

In the above figures, the horizontal coordinate represents the top of the layer in tender soil investigation. While the vertical coordinate is the top of the layer in post-tender soil investigation. If a point located above the diagonal line, this means that its elevation in the post-tender soil investigation is higher that its elevation in tender soil investigation. Figure(3.1a) shows that the ground surface in both, tender and post-tender,soil investigations boreholes is almost the same. For the sandstone layer, Fig (3.1b) shows that top surface elevation of the sandstone for the post-tender soil investigation boreholes is higher than it in the tender soil investigation boreholes.

3.3.1.5. Original soil investigation scope

Media production city studios have been designed to be constructed on about 15.7 faddan (about 66,000 m^2). In the soil investigation stage, Eighty four (84) boreholes have been taken up to 10.0 in depth from the ground surface. This means that there is one borehole for each

785m^2. According to the Egyptian code of practice for soil mechanics, design and execution of foundations (2001), the boreholes number for such type of constructions must be at least one borehole for each (300m^2 to 500m^2). This means that the number of boreholes does not match the code requirements. Where, according to the code requirement, the minimum number of boreholes should be between 132 and 220.

3.3.1.6. Soil investigations cost

The soil investigation cost has been calculated according to the unit price of bored length in rock and sand layers; this means that the price of the soil investigation for this project was calculated based on the total boreholes length with different prices for sand and rock. The price of boring in the rock layer is more than the price of boring in the sand layer. The length of boring in the rock layers was about 545m and the length of boring in the sand layers was about 250m. The prices for boring at the time were 50 LE/m and 20 LE/m for rock and sand respectively. The total soil investigation cost after adding the boring machine transportation cost was about (LE 43,000).

According to the Egyptian code of practice the minimum number of boreholes should be between 132 and 220. Accordingly, the minimum cost of the required soil investigation can be estimated. The soil investigation could be estimated based on the average cost per borehole. The original soil investigation total cost is (LE 43,000) for 84 boreholes, so the cost per borehole is about LE 512. If the number of the boreholeshave taken according to the code requirements, the cost of the soil investigation should be between (LE 67,584) and (LE 112,640).

3.3.1.7. Comparing the excavation cost based on the two soil investigationstages

According to the tender soil investigation the quantity of the excavation volumeshould be be 92,349 m^3 divided to 38,389 m^{3}excavation in rock and 54,560 m^{3}excavation in sand. After the reconsiderations of the thickness of the sands and rock, the total excavation volume was founded 94,689 m^3. This quantity is 2.50% more than the total amount estimated based on the tendersoil investigation. This is an acceptable tolerant because the two values are relatively close. The total amount is divided to 77,856 m^3excavation in rock which is 102.80% more than the total amount estimated based on the tendersoil investigation, and 16,833 m^3 excavation in sands which is 30.95% of the total amount estimated based on the tendersoil investigation.

Table (4.1) isshowing the excavation quantities and costs of the excavation according to the original and the post-tender soil investigation. The prices for the excavation are according to Shafei(2000).

Table (3.1) Excavation cost based on the two stages of the soil investigation

According to original soil investigation				
Item	Unit	Rate (LE)	Quantity	Price (LE)
Excavation in Sand	m^3	10	54,560	545,600
Excavation in Rock	m^3	25	37,789	944,725
Total				1,490,325
According to post-tender soil investigation				
Item	Unit	Rate (LE)	Quantity	Price (LE)
Excavation in Sand	m^3	10	16,833	168,330
Excavation in Rock	m^3	30	77,856	2,335,680
Total				2,504,010

The estimated cost of the excavation based on the original soil investigation was (LE 1,490,325). While estimated excavation cost based on the after-tender soil investigations of this is LE 2,504,010 which is 68% more than the estimated cost.

3.3.1.8. Extra cost due to this problem

In order to identify the problem and to study the contractor claim, an additional soil investigation has been made. The total extra costs thatcan be considered as extra due to this problem are the post-tender soil investigation cost and the cost of the consultancy service to identify the problem including geotechnical comparison report. The cost of the extrasoil investigation was (LE 88,963), while the cost of the consultancy service to identify the problem including geotechnical comparison report was (LE 18,000). This means that the extra cost is about (LE 106,963).

The cost of the soil investigation to fulfil the code requirements is between (LE 67,584) and (LE 112,640). The extra cost represents 1.6 times the minimum cost and 0.9 times the maximum cost of the required soil investigation.

3.3.1.9. Comparing the excavation duration according to the original and post-tender soil investigation

The duration of the excavation has been estimated according to field records for other projects. The tendersoil investigation described the rock layer as moderately weak sandstone, while according to the post-tender soil investigation and field, the sandstone description is moderately strong. The difference in the rock strength affects the excavation rate for the same breaker. The rock breaker production rate in the weak rock is more than in the strong rock. The excavation duration according to the original and post-tender soil investigations is as following.

- **Original soil investigation (Moderately weak rock)**
  - Rock volume is 37,789 m^3. While the excavation rate for one rock breaker is about 300m^3/day, then excavation time for one rock breaker is about 126 days.
  - Sand volume is 54,560 m^3. While the excavation rate for one loader is about 3000 m^3/day, then the excavation time for one loader is about 19 days.
  - To reduce the excavation time it will be assumed that five rock breakers will be used in addition to one loader for sand then the total excavation duration will be about 25 days.

- **Post-tender soil investigation (Moderately strong rock)**

For the comparison purpose, it will be assumed that the same equipments will be used.

- Rock volume is 77,856 m^3 and the excavation rate for one rock breaker is about 190m^3/day, then excavation time for one rock breaker is about 410 days.

- Sand volume is 16,883 m^3 and the excavation rate for one loader is about 3000 m^3/day, then the excavation time for one loader is about 6 days.
- For the comparison purpose it will be assumed that the same five rock breakers and one loader for sand will be used then the total excavation duration will be about 82 days.

According to the simple comparison above the excavation duration in the field is about 3.28 times the estimated duration.

The actual delay was 6 months, but this time was not only due to the excavation time only, it was due to the arbitration between the owner and the contractor. This delay duration has been known by asking the people who have workedin this project. Since the project duration was supposed to be three years, the actual delay represents 16.7% of the project total duration.

3.3.2. Upgrading Cairo/Alexandria/Matrouh Desert Road to Freeway

3.3.2.1. Project description

Cairo/Alexandria/Matrouh highway is one of the most important highways in Egypt. For the purpose of increasing the highway capacity and designed speed, the General Authority for Roads, Bridges and Land Transport (GARBLT) made a decision to upgrade this highway to a freeway. The British Standards define the free wayhighway as limited access dual carriageway road not crossed on the same level by other traffic lanes, for the exclusive use of certain classes of motor vehicles. The length of the targeted segment of road to be upgraded was 169Km (between Km 29 and Km 198). To accelerate the construction process, the road has been divided into five (5) sectors. There is a different contractor for each sector of the road. The sector under study is sector five.

3.3.2.2. Original soil investigations

The geotechnical investigation report was issued in 2006. The report consisted of twenty seven (27) boreholes that were taken up to 20.0 in depth from the ground surface. The report indicated that the soil formation shows variation and includes different layers of fill, sand, clay, limestone and lime mud, which are not uniformly distributed along the site. The laboratory tests include unconfined compression test, one-dimensional swelling test and chemical analysis of soil samples. It should be noted that no collapse potential tests were taken.

Sector five length is 34 Km from Km 126 to Km 160.Number of boreholes in this sector is threeboreholes.

3.3.2.3. Problem

About one year after the construction (laying out the Pavement), through a segment of about 2.25 km of the road, alligator cracks were observed on several spots along the road segment. Figures (3.2 to 3.4)showthe road cracks, cracks extension along the road, cracks extension into the base layer, and the taken cores samples in the cracked part of the road.

Figure (3.2) Cairo/Alexandria freeway cracks

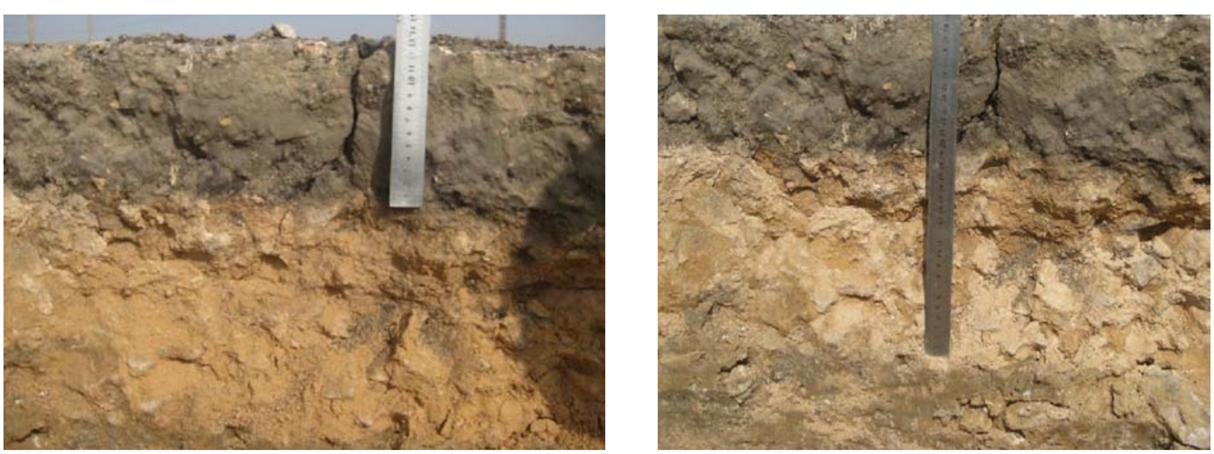


Figure (3.3) Cracks extended to base layer

Figure (3.4) Core sample on cracks shows deep cracks along sample

3.3.2.4. Causes

Test pits were excavated by the contractor down to depths between 2.75 m and 3.60m. Samples were collected from test pits and transported to the laboratory for testing to identify the cause of the cracks. The laboratory results, specially the collapse potential tests, indicated that the natural soil in the subsurface is sensitive to water, and indicated collapse or compression of the soil upon water access to the soil for any reason. Figure (3.5) shows soil below the freeway pavement:

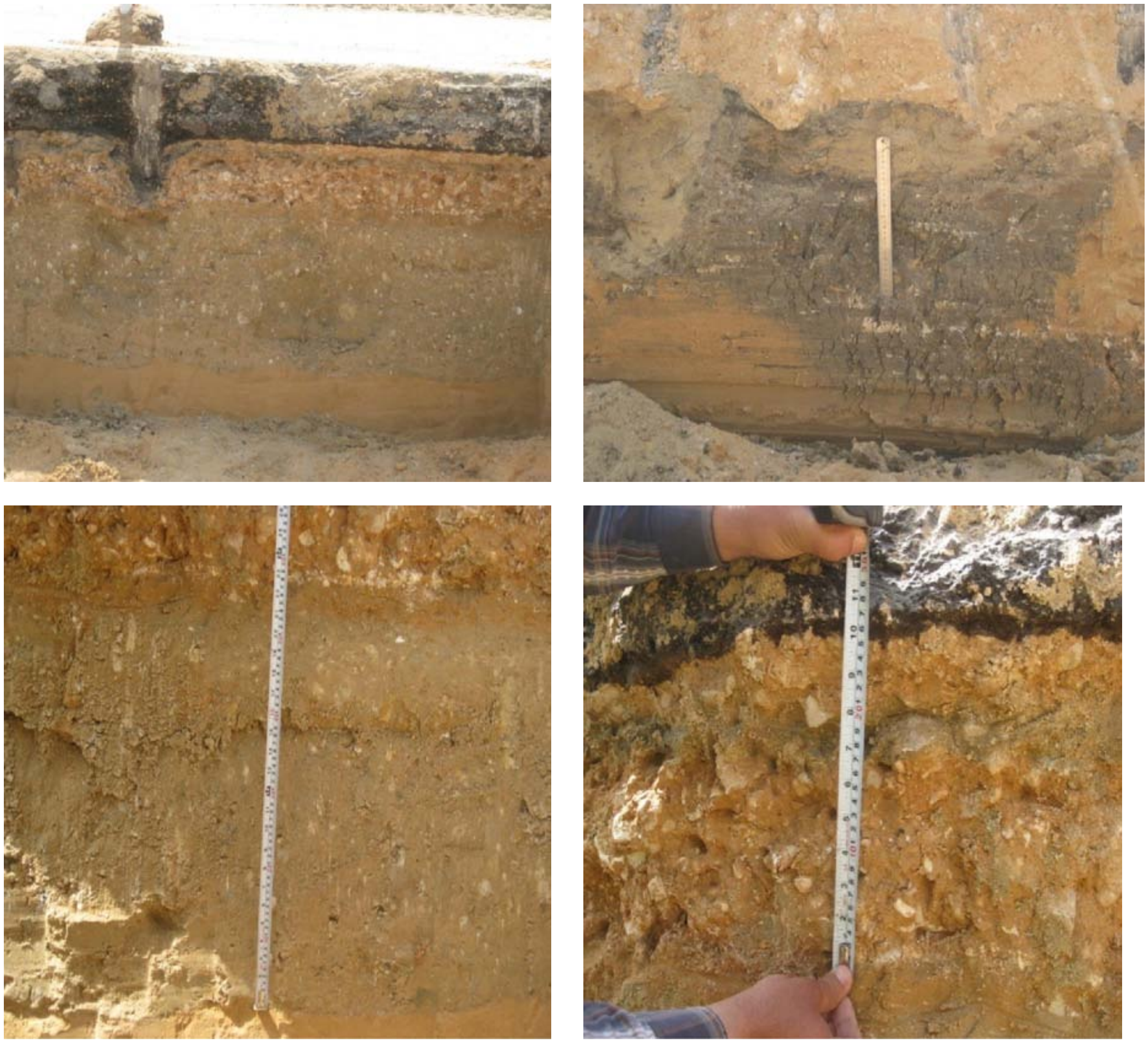


Figure (3.5). Collapsible soils under the road base layer

Problem subgrade materials consisting of collapsible soils are common in arid environments, which have climatic conditions and depositional and weathering processes favorable to their formation (Houston, 1988).

Collapsible soils have high void ratios and low densities and are typically cohesionless or only slightly cohesive. Collapse of the "cemented" soil structure may occur upon wetting because the bonding material weakens and softens. The soil is unstable at any stress level that exceeds that at which the soil had been previously wetted. Thus, if the amount of water made available to the soil is increased above that which naturally exists, collapse can occur at fairly low levels of stress, equivalent only to overburden soil pressure. Additional loads, such as traffic loading or the presence of a bridge structure, add to the collapse, especially of shallow collapsible soil. The triggering mechanism for collapse, however, is the addition of water (Houston, 1988).

3.3.2.5. Corrective action

Because of availability of the collapsible soils under the road layers, and to avoid any future problems due to the availability of the collapsible this soil under the highway, the best corrective action is to remove the first meter of this soil and replace it by structural fill soil as recommended by the project recommendations and specifications.It is stated in the project recommendations and specifications that if collapsible soil appears during excavation, the excavation should be extended at least 1.0m below the base layer. This soil should be replacedby clean sand or crushed rocks. By default, the corrective action should include removing the asphalt layers and under-laying layers into the collapsible soils. This means that the rehabilitation should included removing the paved asphalt layers and removing the top one meter of the beneath natural soil. Then, reconstructing the road with one meter of clean replacement should according to the project specifications.

3.3.2.6. Original soil investigation scope

The length of the studied sector is 34 km. This sector soil investigation consists of three boreholes, at Km126.3, Km147.5 and Km157. Each borehole was taken up to 20.0 in depth from the ground surface. The soil investigation report indicated that the soil formation shows variation and includes different layers of fill, sand, clay, limestone and lime mud, which are not uniformly distributed along the site. According to the Egyptian code of practice for roads construction, the boreholes number for road constructions must be at least one borehole for each kilometer of the road. This means that the number of boreholes does not match the code requirements.

3.3.2.7. Original soil investigation cost

The cost of soil investigation is calculated by the cost of the 1.0m length of the borehole plus the equipment transportation cost. Sector Five Length is 34 Km from Km126 to Km 160. Actual number of boreholes in this sector is 3 Boreholes.The boring cost of is (LE 120) per meter length of the borehole in addition to the equipment transportation cost of (LE 2,800).

Since the number of boreholes is three with length of 20.0m for each borehole, the total cost of soil investigation is (LE 10,000).

3.3.2.8. Comparing original with typical soil investigation costs

Total cost of this sector is LE 703,767,014 including the cost of road construction, cost of bridges construction, cost of planting, cost of lightening and signs and signals. While the road construction works cost is LE 335,476,900. Typicalsoil investigation cost for roads is between (0.20% and 1.55%) of road cost, so the typicalsoil investigation cost is as following.

$$= (0.20\% \sim 1.55\%)\ x\ 335{,}476{,}900$$

$$= LE\ (\ 670{,}954 \sim 5{,}199{,}892)$$

While the actual soil investigation cost is (LE 10,000), so the percentage of actual soil investigation cost to total road cost= $\frac{10{,}000}{335{,}476{,}900}\ x\ 100 = 0.003\%$

3.3.2.9. Rehabilitation cost for these problems

Figure (4.1) shows the typical cross section for the road.

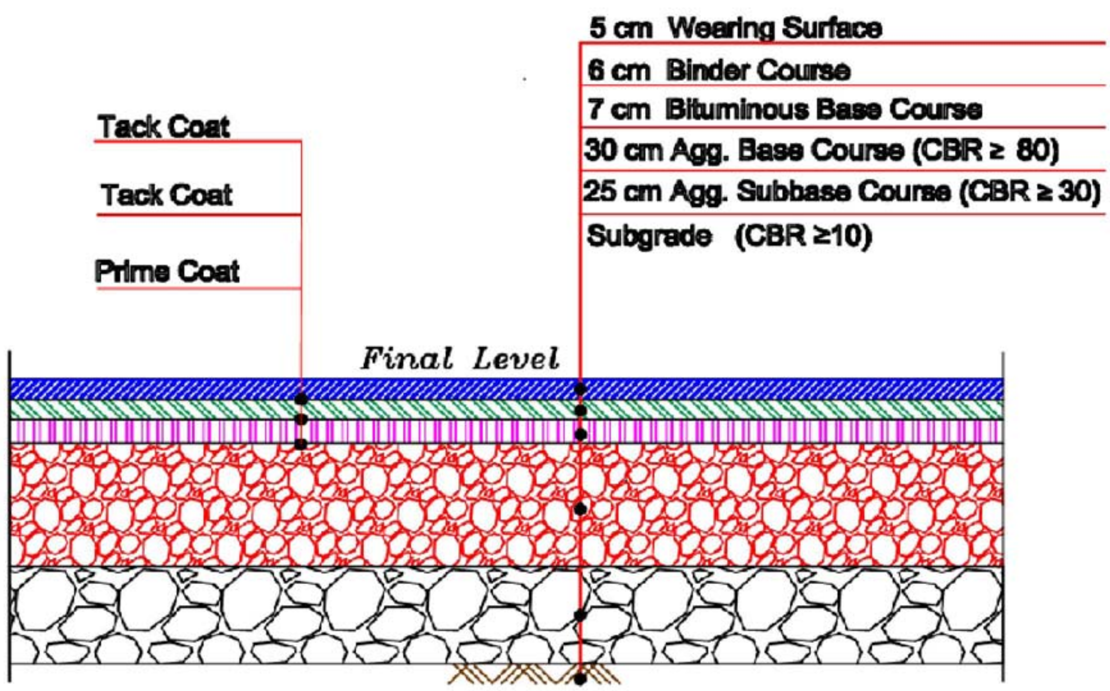


Figure (3.6): Typical road cross section

Based on the above cross section and project contract prices, Table (4.2) shows Rehabilitation cost calculations:

Table (3.2) Rehabilitation cost for the damaged segment in Cairo-Alex. desert road

Cracked part length is about 2.25Km, and the road consists of 4 Lanes, 3.75m Each → Surface area = 4x3.75x2250=33,750m^2

Item	Unit	Unit Price (LE)	Quantity	Price
Remove the Existed Asphalt Layers for any Depth	m^2	32	33,750	1,080,000
Removing Collapsible Soils (100cm Thickness)	m^3	8.0	33,750	270,000
Replacement by Subgrade CBR ≥10 (100cm Thickness)	m^3	18	33,750	607,500
Subbase CBR ≥30 (25cm Thickness)	m^3	45	8,438	379,688
Base CBR ≥80 (30cm Thickness)	m^3	140	10,125	1,417,500
Prime Coat (MC-30)	m^2	3.5	33,750	118,125
Bituminous Treated Base (7.0cm Thickness)	m^2	28	33,750	945,000
Tack Coat (RC-3000)	m^2	1.5	33,750	50,625
Binder Course (6.0cm Thickness)	m^2	30	33,750	1,012,500
Tack Coat (RC-3000)	m^2	1.5	33,750	50,625
Wearing Surface (5cm)	m^2	27	33,750	911,250

Total	LE 6,842,813

It should be noted that the rehabilitation cost which had been taken to consideration is only the road itself rehabilitation, there are additional costs could be taken to consideration such:-

- Soil Exploration (Field and Laboratory tests which has been taken to identify the problem causes.
- Cost of transforming the traffic way into the other direction (Signs, Barriers …etc.).

- Environmental cost due to the possible traffic crowed (the two directions volumes will be carried by one direction road lanes).
- Risk of repetition the same problem in other segments of the road.
- Any additional problems might appear later.

3.3.2.10. Comparing typical soil investigation with the rehabilitation cost

As mentioned before in this chapter, typicalsoil investigation cost ranged between (LE 670,954) and (LE 5,199,892). The rehabilitation cost is (LE6,842,813) which represents 10.2 times the minimum typicalsoil investigation cost and 1.3 times the maximum typicalsoil investigation cost. By comparing the rehabilitation cost with the construction cost which is (LE 335,476,900). The rehabilitation cost represents 2.04% of the construction cost.

If we consider that the minimum typicalsoil investigation should be perform. Soil investigation cost should be (LE 670,954), which means that number of boreholes that should have been taken as following.

$$Totallengthofboreholes = \frac{670{,}954 - 2800}{120} = 5568m$$

Assuming that the borehole depth is 20m as already taken for actual soil investigation, we get:

$$Number\ of\ borholes = \frac{5568}{20} = 278\ boreholes$$

This means one borehole should be taken at maximum space of 122.3 meter between the successive boreholes.

3.3.2.11. Time extension due to the problem

The length of the road part that has to be removed and reconstructed is 2.25 km, and the total length of the road sector is 34 km. Assuming that the construction of this part will be at the same rate as road construction rate, this means that the construction duration is equal to the percentage of the length of the removed part to the sector length in addition to the time required to remove the cracked part and the collapsible soil.This means that the reconstruction time is about 6.6 % of total duration if the removing of the current asphalt time is considered being insignificant.

3.3.3. Al-Ertika'a Factory in 6th of OctoberCity

3.3.3.1. Project description

Al-Ertikaa Factory is a recycling factory at the site of Low Cost Housing project at the 6th October and includes the following buildings:

a) Administration building
b) Restaurant hall
c) Two residential buildings for technicians and labors
d) Factory building

The main philosophy of the low cost project is to economize the used construction material. Each building consists of number of adjacent units. Each unit consists of a room, hall, kitchen and bathroom, and consists of one floor (ground floor) only. The building structural system is wall bearing founded on strip footing foundations. Walls are constructed of red bricks and limestone blocks. The foundations are strip reinforced concrete over plain concrete. The depth of the foundation is less than 1m below the ground surface. Information from the site indicates that there is a replacement fill of unknown thickness placed below the foundations. The probable thickness of the replacement fill is about 1.5 to 2.0 m.

3.3.3.2. Original soil investigations

Al-Ertikaa Factory is part of the low cost housing project. Since the philosophy of the low cost housing is to construct the building with minimum cost, then the project owner, consultant and contractor decided to reduce the number of site investigation tests as much as possible. Soil investigation tests were taken randomly on the whole project area without taking into consideration buildings locations. Although that the code requirement stated that the minimum number of a soil investigation tests is two boreholes to depth of ten meter at least for each building, the contractor adopted the knowledge of the geology of the area, and the knowledge of the soil interpretation from the previous soil investigation in the project to predict the soil stratigraphy at the factory location. Based on the previous soil investigation,the soil in this buildings locationshould be mainly sand, sandstone, and clay. In these regions of the project, the clay has indicates possible high intrinsic expansiveness, and the sand was poorly graded and contains silt, gravel or clayey.

3.3.3.3. Problem

Directly after finishing the construction of the factory, cracks start to shown. The damaged structures are the two residential units for technicians and labors. The rest of the structures suffered no observed damage or cracks. Some of the cracks are dangerous on the residents especially at the middle units where concentrations of the cracks caused fall down for ceramic slabs.

Figure (3.7) Factory buildings cracks

3.3.3.4. Causes

According to the consulting services report the damage reason was the presence of swelling clay under the replacement fill under the foundations. The clay has free swell values in the range of 75% to 220% and one dimensional swelling pressure upon inundation of 2700 kPa. These numbers indicate high intrinsic expansiveness and swelling potential of the clay. The clay exists in the site from depth about 1 m and extends down to depth 4 to 5.5 m below the ground surface. This means that the swelling clay exists under the replacement fill that is under the foundations. Planting green areas and trees adjacent to the damaged buildings introduced water to the subsurface formation. The fact that replacement fill is sand which is permeable material facilitated the seepage of water to the swelling clay under the replacement fill. The swelling of the clay caused differential vertical displacement that caused distress to the walls and domes of the buildings.

Expansiveness quality is arising in clay soils. Clay soil particles are very small and are shaped like very thin plates; due to the thin plate shape, clay particles have a lot of surface area for their size. The clay particles are electrically charged and bond to each other like small magnets. The electrical bonding force is relatively weak and can be easily broken by water molecules that become inserted between the clay particles. As the soil becomes wetter, more and more water molecules attach themselves to the plate-shaped clay particles and the water molecules push the clay particles further and further apart. This results in the apparent volume of the soil mass growing so that there is soil heave or expansion. As the soil dries out, the process reverses; as the water molecules evaporate and become detached from the clay particles, the clay particles move closer and closer together. This results in soil shrinkage. In a sense, expansive soils act like a sponge; the apparent volume of the sponge increases as it takes on water and shrinks as the water evaporates (Gray and Gray, 2004).

3.3.3.5. Corrective action

To rehabilitate the current damages and prevent future possible damages the following action was suggested by the consultant:

Planting, irrigation and Water Infiltration Control

1) All the trees that are adjacent to the damaged building should be immediately moved to a distance of at least 1.5 m away from the buildings. It is preferable to construct sidewalks of at least 1.5 m wide around the perimeter of each building. The sidewalks should be sloping away from the building by 1:15.
2) The tree planting and the green areas should be in controlled and isolated basins. This means that in each basin, under the planting soil should be isolated by high density polyethylene sheets to seal the irrigated volume of soil.
3) Irrigation of green or planted areas should be performed by using dripping or sprinkling system only.
4) No continuous leakage or streaming of water is allowed to the soil around the buildings.

Water supply and waste water drainage

Information about water supply and waste water drainage systems are not available. However, it is assumed that the following recommendations were followed during construction:

5) All water supply and sewage drainage should be fixed to outside walls and its connections must be flexible, executed to the highest standards and under strict engineering supervision.
6) Any buried pipes should be flexible and tightly connected.
7) Manholes should be at least 2 m outside the building limits.
8) All sewer pipes should have flexible joints.

In spite of the fact that there is no sign of any leakage of utilities in the site, the following recommendations should be followed:

9) All water supply and sewage drainage lines and connections should be inspected and tested to make sure that they are free of any leakage.

Monitoring of vertical displacements

10) Monitoring of vertical displacements at Elevation Reference Points should continue to longer period of six months, during which the monitoring records should be frequently reviewed. The six months period may be renewed for another period depending on the trend of the monitored records.

Strengthening and repair works

After making sure that monitoring records indicating that vertical displacements are at rest for considerable period of time, the following strengthening and repair works should start:

11) In case of cracks in the domes and arches that are completely through the entire thickness of the member, the roof including the domes and arches shall be shored using suitable shoring system.
12) In cases of cracks that have crack width less than 2 mm, the cracks shall be widened, cleaned, and filled with non-shrinkage grout. Sheets of galvanized steel wire mesh shall be placed over the crack area from outside and be fixed using steel nails. The treated areas should be plastered using cement paste.
13) In cases of cracks that are through the entire thickness of the member with a crack width more than 2mm, the members (dome, arch or wall) should be removed and reconstruct them using the same original construction material according to proper technical specification.

3.3.3.6. Original soil investigation scope

Since the philosophy of the low cost housing is to construct the buildings with minimum cost.The project owner, consultant and contractor decided to reduce the number of soil investigation tests as much as possible. They adopted the knowledge of the geology of the area and the knowledge of the soil interpretation from the previous stages of the project to predict the stratigraphy and properties of the soil of the factory location. So, there is no boreholes have been taken at the construction location. The closest borehole log was far from the construction location. Thus, the original soil investigation cost for these buildings could be considered zero.

3.3.3.7. Rehabilitation cost for these problems

The actual corrective action for these problems which performed in the site was as following.

a. Soil investigation was made to identify the cause of the buildings cracks.
b. All the trees that are adjacent to the damaged building were moved to a distance of at least 1.5 m away from the buildings.

c. A plastic sheets U-shape were Performed to prevent irrigation water from leaking to the soil under the buildings.

d. Monitoring of vertical displacements at elevation reference points for period of two months.

e. Replanting the landscape area including filling with agricultural soil implementation on an appropriate sprinkler irrigation system

f. Rehabilitation the building cracks and replace the buildings damaged elements.

The rehabilitation cost for the items that performed in the site were as in Table (4.3). These costs have been obtained from the consultant engineer at the site.

Table (3.3). Rehabilitation cost for the damaged buildings in Al-Ertika'a Factory

No.	Item	Unit	Rate (LE)	Quantity	Price (LE)
a	The extra soil investigation cost	L.S.			8,750
b	Removing the trees which are adjacent to the buildings to a distance of 1.50m from the buildings. Including changing the manholes places and sewer lines paths.	m^2	150	450	67,500
c	Performing plastic sheets U-shape to prevent irrigation water from leaking to the soil under the buildings.	m^2	15	700	10,500
d	Monitoring recording of vertical displacements at Elevation Reference Points for a period of two months.	Day	150	60	9,000
e	Replanting the landscape area including filling with agricultural soil implementation on an appropriate sprinkler irrigation system	m^2	250	450	112,500
f	Fixing structural damages and replacing some parts. This item includes fixing the building cracks	L.S.			25,000
Total Cost					233,250

It could be considered that there is part of these costs does not considered as rehabilitation. This is because of the availability of the clay before the construction. So, it would have done if soil investigation made before constructions. These items are items b and c. Accordingly the rehabilitation cost could be considered as a consequence for ignoring soil investigations is due to the items a, d, e and f. The rehabilitation cost is (LE 155,250)

It should me mentioned that by removing the trees and protecting the building underlain soil from any source of water there is no need to make any adjustment for the soil. The building has small weight and then the stresses on the soil are low stresses.

3.3.3.8. Comparing the rehabilitation cost with the construction cost

The total cost for the buildings including landscape cost was (LE 363,150). By comparing the rehabilitation cost to the construction cost (LE 155,250) it could be concluded that the rehabilitation cost represents 42.8% of the total construction cost. While According to the Egyptian code of practice for soil mechanics, design and execution of foundations (2001), the boreholes number for such type of constructions is to be at least two boreholes if the area less than 300m^{2}and to a depth of 10 m, one extra borehole for each (300m^2 to 500m^2).Since the area of each building is about 222 m^2, then the number of boreholes should be four boreholes for the two buildings. The cost of the four boreholes is about (LE 3550). This that the rehabilitation cost is43.7 times soil investigation cost.

3.3.3.9. Comparing the typical soil investigation with the rehabilitation cost

According to theEgyptian code of practice requirements, the soil investigation cost for these buildings must beat least (LE 3550). The rehabilitation cost is (LE 155,250) which represent 43.7 times the requiredsoil investigation cost.

3.3.4. Gardens Hillside View Villas

3.3.4.1. Project description

Hillside Development comprises of 208 two-story villas in Dubai, constructed on a hillside in blocks of two-villa each (Fig., 3.7). Before villas construction, site was subjected to grading. Some villas were founded on fill, others were found on cut. A building unit consists of two villas. The size of the unit in plan is approximately 20mx20m and villas share common walls in the middle. The units may be either spaced or adjacent to each other with no space in between.

The structural system of each unit (two villas and annexes) is a reinforced concrete skeleton (i.e. footing, beams, slabs, columns). The two villas share in the middle common wall and I shaped reinforced concrete core extending to the height of the ground floor only. Structurally, the two villas are connected through common columns, continuous beams and continuous ground beams.

The foundation system is shallow isolated footings placed at 2.0 m below the ground floor level or about 1.3 to 2.0 meters below the current ground surface. The columns are connected to each other under the walls with grade beams near the ground floor elevation and well above the foundations level.

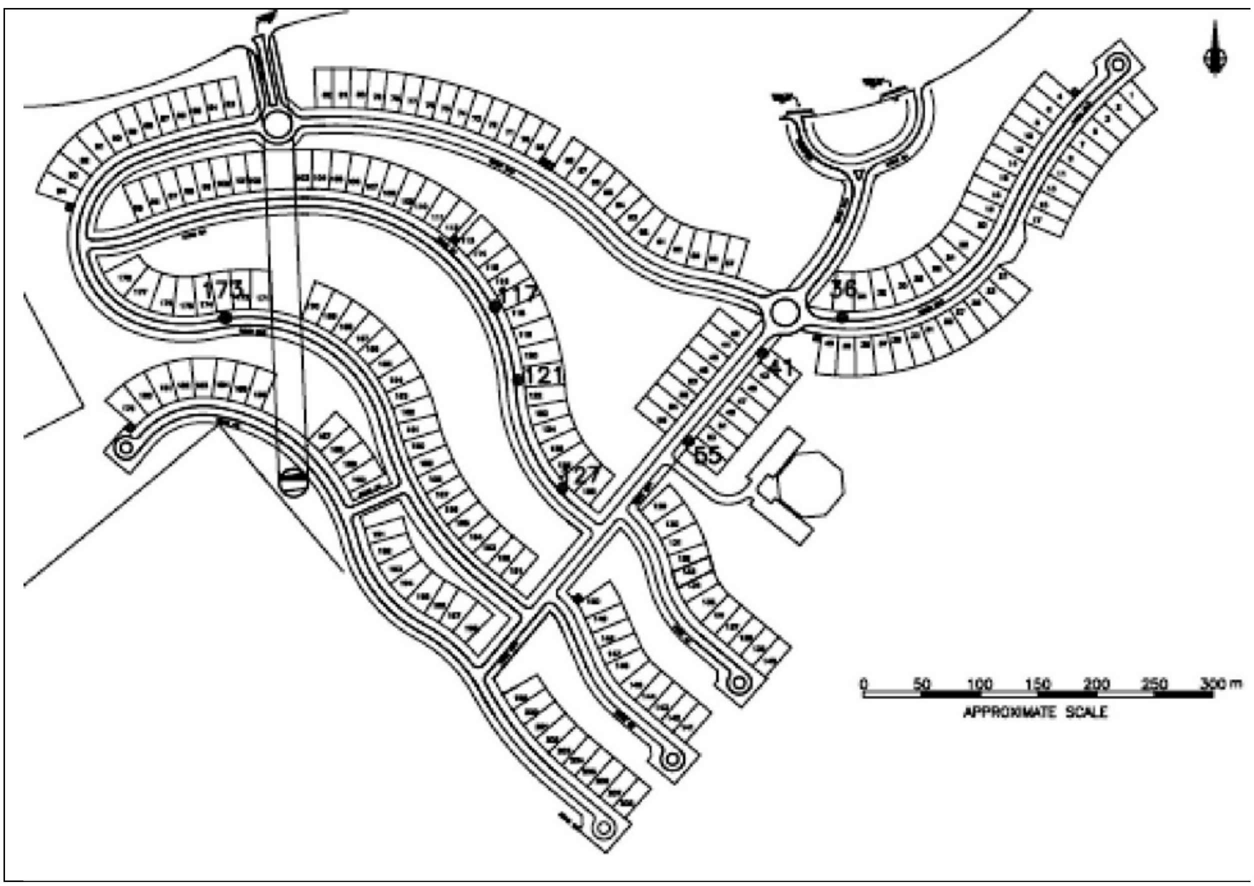


Figure (3.8). Gardens Hillside View villas layout

3.3.4.2. Original soil investigations

A soil investigation had been carried out before construction in the beginning of 2002. One borehole was taken at the location of each villa up to 6.0m depth from ground surface. The report indicated that the soil formation has variation and the soil is almost medium dense, dense to very dense sand.

3.3.4.3. Problem

Villas construction was completed before March 2003.Significant diagonal, horizontal and vertical cracks (Fig., 3.7) appeared in the concrete block walls. These cracks were first observed in mid-June 2003 (at least in 8 villas). In the September 2003 the number of cracked villas reached to 48. Cracks have been noticed within three to four months after end of construction and about two months after the potable water supply is connected to villas. Although vertical and horizontal cracks have been observed, diagonal cracks were most predominating.

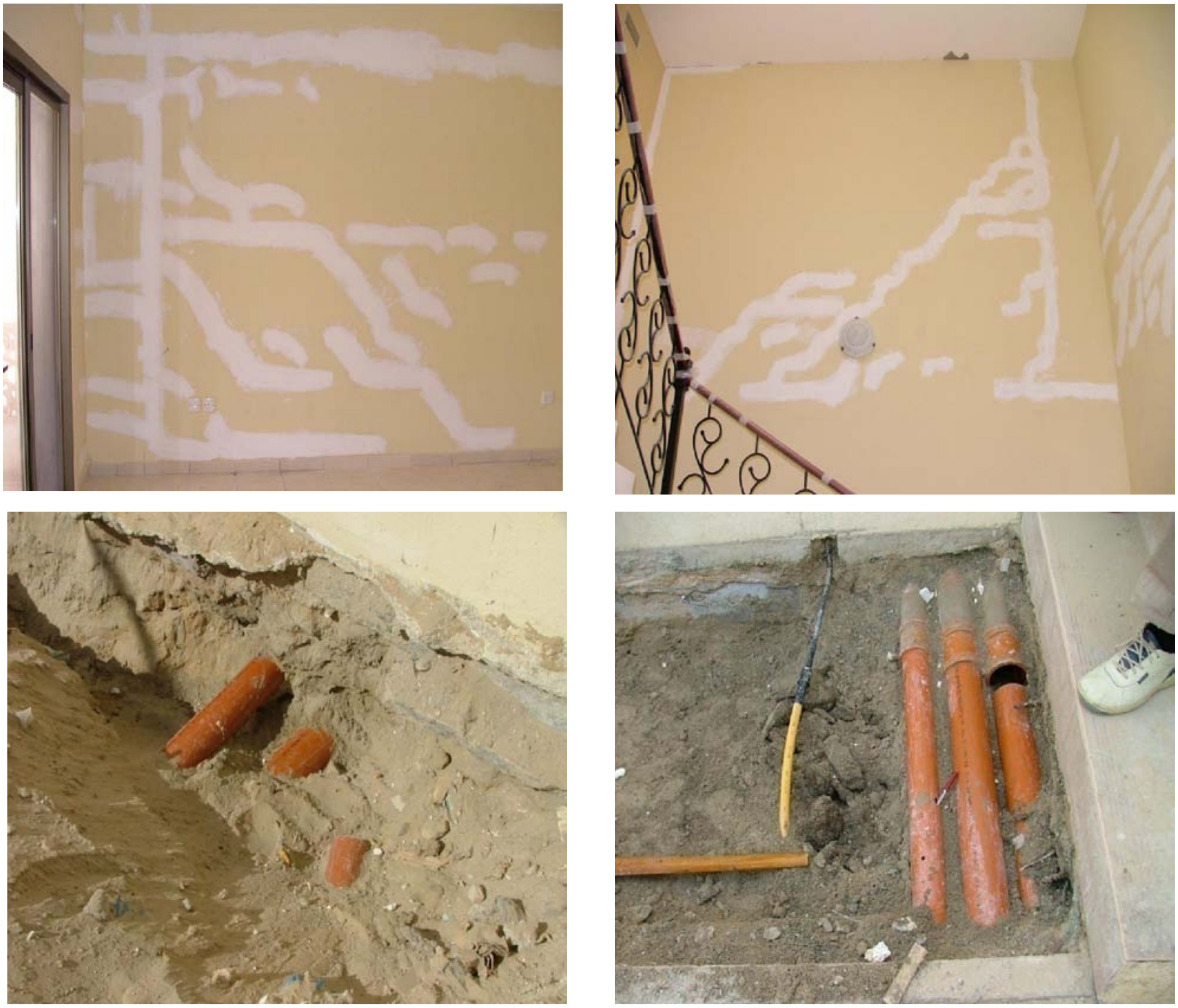


Figure (3.9). Gardens Hillside View Villas cracks, and broken sewerage pipes due to the differential settlement

3.3.4.4. Causes

In order to investigate the causes of cracking of villas, some of the most cracked buildings are examined. The approximately assessed cracking patterns indicate that the main cause of observed damage might be due to expansive behaviour of the foundation soil. In order to investigate the causes of the observed damages, geotechnical field work was carried out.

The boreholes shows that ground the top soil layer is predominantly sand, 1.6 to 2.5 meters thick, most probably the man made fill above the foundation level. This fill is encountered in all boreholes and the natural soil is encountered further at depth.

The natural ground to the investigated depth is mainly calcareous fissured clay of high plasticity, of very hard to hard consistency with scattered gypsum veins. Gypsum veins are of variable thickness. In some boreholes, the thickness of gypsum is a few millimeters to centimeters, though in some villas the thickness is of the order of magnitude of meters. Fissuring observed in almost all clay core samples indicates some form of the movement, shrinking or shearing in particular, a sure sign of active soil.

Extensive testing was carried out to assess the behavior of clay when influenced by the change in moisture content, which has occurred in foundation soil. Results show that the soil is highly expansive.

The main cause of the observed diagonal cracks is the differential movement of foundations. The differential movement is caused by the differential heave of foundations due to the presence of the expansive soil beneath the foundations and to ingress of water that occurred in several incidents. Comparatively fast heave has happened due to an incidental leakage from broken utility lines of sewage, water supply and chilled water pipes in a number of cases. However, even in the absence of any water utility failures, in time, significant soil heave and damage might be expected for some villas with certain time lag of 2-3 or more years due to moisture migration from the humid hot air towards the cooler soil space beneath the building and due to landscape irrigation provided that expansive soil exists beneath foundations.

However, not all the visible cracks can be attributed to the differential foundation movement. Some vertical and horizontal cracks are the consequence of poor workmanship, extreme temperature, poor or no curing of mortar and other causes.

3.3.4.5. Corrective action

To rehabilitate the current damages and prevent future possible damages the following actions were suggested:

a) Geotechnical soil investigations to characterize the geomaterial formation of each villa.
b) Monitoring the villas in the site. The elevation versus time relationship provides an interpretation to the behaviour of the subsurface geomaterial.
c) Detection of the leakage in under-villas utility pipelines.

d) Irrigation optimization by reviewing irrigation system for the villas and landscape to minimize the irrigation process and minimize the water seepage to foundation clay.
e) Chemical treatment of expansive clay to reduce expansion.
f) Increase rigidity of the skeleton of the villas to withstand the differential vertical movements with minimizing the transfer of strains to the walls of the villas.
g) Repair damages after the solution of the problem and after deciding that there is no significant ongoing vertical movement.

Another method was suggested. This method is by strengthening the soil beneath foundations. This strengthening is by drilling inside the building with crawler mounted, the inserting a steel bar into the drilled hole. Then,stiff grout will beinjected into the ground using a temporary casing. This grout consists of Portland cement with sand and water. This depth of injection is 6.0m below the footings surface.

3.3.4.6. Original soil investigation scope

A soil investigation had been carried out before construction. The boring had been started in January, 2002 at the site. Although that the minimum number ofsite investigation tests is two boreholes up to 10.0m depth at least for each building (Mayne*et al.,* 2002), but there was only one borehole taken at the location of each villa up to 6.0m depth from ground surface.

3.3.4.7. Original soil investigation cost

Four building units each of them consists of two villas have been taken as an example to illustrate the detailed cost for all types of cost. The original soil investigation is one borehole up to depth of 6.0 m. The cost of the original soil investigation has been estimated using the cost per meter length of the borehole log in addition to the mobilization and transportation costs. In each building unit, two boreholeswere taken up to 6.0m length. The cost per meter length was about 170 Dhs/m (UAE Dirham per meter length) and (Dhs 900) for mobilization and transportation. The soil investigation cost for the four buildingswas (9000 Dhs).

3.3.4.8. Comparing soil investigations cost with foundations cost

Based on literature survey conducted in chapter two of this thesis, the typical cost values for soil investigation in buildings projects are between 0.05% and 0.20% of total project cost, or between 0.5% and 2.0% of foundations cost. Due to unavailability of the total construction cost, the soil investigation typical cost will be estimated in relation to the estimated foundation cost. Based on the foundation footings dimensions, the total cost for the foundations is calculated as following:

Table (3.4) foundations cost for one unit (two villas) of Gardens Hillside Villas

Item	Unit	Quantity	Rate (DHs)	Cost (DHs)
Excavation	(m^3)	7761.3	50.0	388,064
Plain Concrete	(m^2)	1197.9	266.7	319,451
Reinforced Concrete	(m^3)	634.5	1593.7	1,011,219
Insulation	(m^2)	15972.5	146.8	2,345,174
Back fill	(m^3)	5928.8	79.4	470,540
Total Cost				4,534,448

These rates have been calculated based ona proposal in 2010 prices. The proposal rates have been transferred to the construction year rates using construction inflation rates which published by construction industry cost tracker (MEED) in the first quarter of 2012.

Typicalsoil investigation cost is between 0.5% and 2.0% of the foundations cost. The calculated foundations cost is (DHs4,534,448), so the typicalsoil investigation cost is as following

$$= (0.50\% \sim 2.00\%) x \; 4{,}534{,}448$$
$$= DHs \; (\; 22{,}672 \sim 90{,}689)$$

The original soil investigation cost is (DHs 9,000), so the original soil investigation cost to foundations cost= $\frac{9{,}000}{4{,}534{,}448} \; x \; 100 = 0.20\%$.

Accordingly, the cost of soil investigation represents 0.20% of the foundations cost which is less than the minimum typical cost of soil investigation of 0.50% of foundations cost.

3.3.4.9. Rehabilitation cost for these problems

The cause of the problem was the expansive behaviour of the foundation soil. To eliminate the expansion behaviour for the soil, two proposals have been submitted to the owner. The two proposals have different methods of rehabilitation but both adopted the same idea which is to solve the problem source. This means that the reason of the differential settlement is availability of weak soil under the building, the solution is to treat this soil. The difference between the prices of these two solutions was the main factor to adopt one of the two solutions. The cheapest proposalto rehabilitate this problem was as following:

a. Drilling, the drilling process includes drilling inside the building with crawler mounted, the inserting a steel bar into the drilled hole

b. Compaction grouting, this process includes injection of a stiff grout into the ground using a temporary casing. This grout consists of Portland cement with sand and water. This depth of injection is 6.0m below the footings surface.

Rehabilitated cost has been estimated based on the adopted cheaperproposal to rehabilitate the source of the villas cracks. The rehabilitation cost should including the cost of the extra site investigation to identify the problem causes, cost of improving the soil and the cost of preparing the structural elements. The detailed cost is as following.

Table (3.5) Total rehabilitation cost for Gardens Hillside Villas

Item	Unit	Rate (DHs)	Quantity	Price (DHs)
Extra soil investigation	m	227.6	62.9	14,315
Soil improvement	villa	239,720	8	1,917,760
Total rehabilitation cost				1,932,075

Another factor should be added to the cost of rehabilitation is the cracks rehabilitation cost. This is a minor cost to comparing with the above costs. So it is acceptable tolerant to neglect this cost.

3.3.4.10. Comparing typical site investigation cost with the rehabilitation cost

From the results shown earlier in this chapter, the typical site investigation cost is ranging between (DHs 22,672) and (DHs 90,689). The rehabilitation cost represents85.2 times the minimum typical site investigation cost and 21.3 times the maximum typical site investigation cost.

3.3.4.11. Time delay due to the problem

The construction time for the selected villas was about one year. One of the purposed solutions to solve the cracks problem was by waiting until soil reaches its maximum settlement, then rehabilitating the cracks problem after the soil settlement stops. The suggested waiting time was about two years. The owner refuses this solution because of the commitment of delivering these buildings to the buyers at certain time. The above studied rehabilitation method was more costly but has shorter duration. According to the rehabilitation proposal, the rehabilitation time is between 3 and 4 weeks for each villa. This means the rehabilitation time is between 12 and 16 weeks. This delay is between 23% and 30% of the construction duration. This time can be reduced by using more than one working team and equipments. Unfortunately, there is no available data concerning how many teams were working in the rehabilitate process.

3.3.5. Yemen News Agency (SABA) building

3.3.5.1. Project description

On the 29^{th} of May 2004 a contract have been signed between the contractor (Elaf Trading and Contracting Company) and the owner (Yemen News Agency) to construct the first phase of a ten (10) floors (1200 m^2 area) with basement building under the supervision of the consultant (Ministry of Public Works and Highways). The first phase consists of the first six-floors and the basement. The contract duration was three (3) years. The foundation system is isolated footings connected with rigid beams and the foundations depth is 5.0m below ground surface.

3.3.5.2. Original soil investigations

A soil investigation had been carried out before construction. The tender geotechnical investigation report was reported in April 2004. Three (3) manual boreholes have been taken at the building location with depths varied from 15.0m to 21.0m from ground surface. The report indicated that the soil formation showed variation and includes different layers of fill, sand, silt and clay.

3.3.5.3. Problem

As a part of the contractual obligations, a confirmation soil investigation has been made by the contractor. Three manual boreholes were taken at the building location with depths varied from 17.50m to 29.10m. The soil investigations results showed that the bearing capacity for the soil is less than the results mentioned in the tender geotechnical investigation report. The suggested isolated footing was not safe to carry the building load because the soil bearing capacity is less than the value used in the original design. Redesigning of the whole foundation systems were carried out, this led to delay the construction time for 8 months.

Although the work commenced after this delay, the financial problem persisted.This led to adisputation between the owner and contractor ended with contract termination in January, 2009.

3.3.5.4. Causes

Site has been delivered to the contractor atthe date of 8^{th} of September, 2004. The confirmation soil investigation showed that the soil bearing capacity is smaller than the value reported before; consequently, the foundations system should be changed. The work was suspended for 8 months to allow re-designing by the owner. During this period of time and exactly in February, 2005 the exchange rate raised in comparison with the local currency. This raise led to a double in the cost of cement, and the reinforcing steel price increased by 50%. Other increases of oil products by (100%) occurred during July 2005 which caused more increases in the material costs.

During the re-designed period a decision was taken to build the building ten(10) floors the basement in one phase, instead of the 6 floors. The new decisions led to a rise in the amounts of material needed more than the allowable increase of materials by 20%. The contractor asked to change the prices of contract items according to the increase in prices of material. The contractor also demanded a compensation for the delay in the project and also to extend the duration of the project as a result of increasing the number of floors.

3.3.5.5. Original soil investigation scope and cost

Six (6) manual boreholes have been taken in two stages (before tender and after tender) at the building location with depths varied from 15.0m to 29.10m from ground surface. This number of boreholes is supposed to be enough to investigate the site soil, where the minimum number of boreholes is two boreholes for areas 100-300 m^2 and one extra borehole for each 300-500 m^2 for areas larger 300 m^2 (Mayne*et al.,* 2002). The soil investigation number of boreholes meets the requirements from the technical side view.

The cost of the original soil investigation for this project was made by a specialist contractor. The cost of soil investigation was (YR 2,400,000).

3.3.5.6. Comparing soil investigations costs with construction cost

The contract price for the building construction based on unit price contract was (YR 612,499,925). While the typical values for soil investigation cost of the total cost in buildings projects are (0.05~0.20) percent of total project cost, or (0.5~2.0) percent of foundations cost.

$$= (0.05\% \sim 0.20\%)\ x\ 612{,}499{,}925$$
$$= YR\ (\ 306{,}250 \sim 1{,}225{,}000)$$

The actual soil investigation cost is (YR 2,400,000), so the present of actual soil investigation cost to total cost= $\frac{2{,}400{,}000}{612{,}499{,}925}\ x\ 100 = 0.39\%$

This means that the soil investigation cost and scope was enough for good interpretation for the soil, but the poor quality and the inaccuracy of the data collected from the original soil investigation was the reason behind the bad interpretation of the soil.

3.3.5.7. Rehabilitation cost for these problems

The cost related to the problem in this case study is hard to be measures because the extra cost of the project is coming from many factors. During the work suspension time for 8 months to allow redesigning by the owner, exchange rate raised comparison with the local currency. This raise led to doubling the cost of cement, while the reinforcing steel price increased by 50%. Another increase occurs for oil products by (100%) caused more increases in the material and labour costs. But it could be assumed reasonably that the extra cost due to thesoil investigation problems is the difference between the planned work that was supposed to be done in the delay time comparing to the actual cost of this amount of work which is perform by new prices due to the materials prices raised.

According to the contractor claim these costs are as following:-

- Office overhead, and assets and equipments depreciation during the stopping period is (YR 7,500,000).
- Difference between the material prices before and after the raising in exchange rate comparison with the local currency (YR 40,000,000).
- The site overhead and the expected profit which was supposed to be gained in case of the project did not stop (YR 34,027,770).

According to the above items the total extra cost is (YR 81,527,770) which represents 13.31% of the project total cost.

3.3.5.8. The time delay due to the problem

The contract construction time for this project was three year. After four and half years (150% of contract construction duration) the finished work was only 38% of the total project construction. This delay was caused by many reasons as illustrated before. The time delay that might be related directly to the sit investigation problem is the first eight months. If it considered that this the only delay related to the soil investigation problem, this delay represents 22.2% of the contract construction duration.

3.3.6. Private Villa in Al-Shorouk City, Egypt

3.3.6.1. Project description

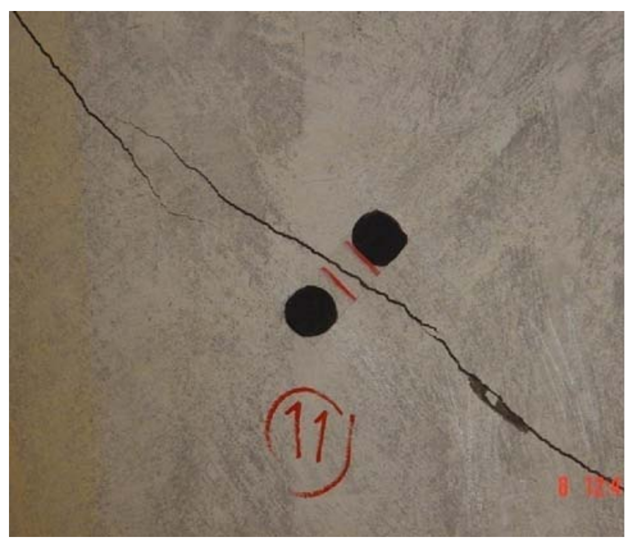
A three stories villa has been built in 1997 in Al-Shorouk city, Cairo. The foundation system was shallow isolated footings connected with rigid beams and the foundation's depth is 1.50m. The structural system for the building is consists of a reinforced concrete skeleton.

3.3.6.2. Original soil investigations

Before starting the construction, two boreholes have been taken up to 10.0m depth below ground surface. The boreholes result show that the subsurface soil is consists of about (5.0m – 5.5m) of sandstone, after the sandstone layer there is a clay layer to the remaining depth of boring. The laboratory tests show that the clay layer has a free swell index between 90% and 125%. These numbers indicate high intrinsic expansiveness and swelling potential of the clay.

3.3.6.3. Problem

After theconstruction completion, significant diagonal and horizontal cracks started to appear. Although horizontal cracks have been observed, diagonal cracks were most predominating. Figure (3.7) shows the cracks that appeared in the villa's different elements.



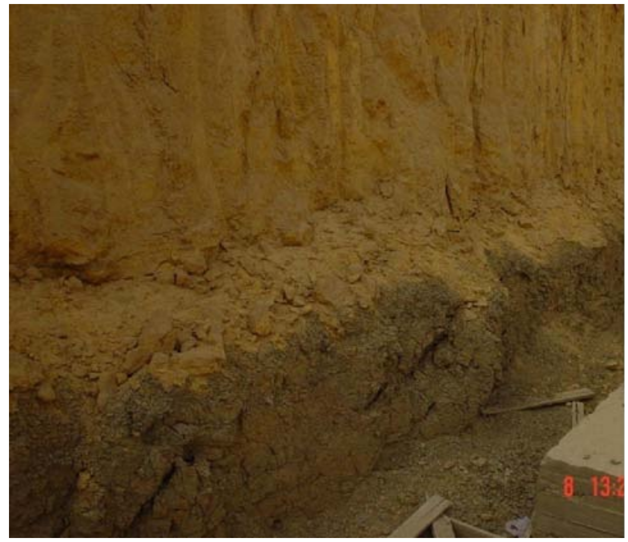


Figure (3.10).Al-ShoroukVilla cracks, and foundation surrounding soil

3.3.6.4. Causes

In order to investigate the cause of cracking of villa, a test pit has been taken to a depth of 2.5m. The test pit shows that the top soil layer is predominantly sandstone;the thickness of this sandstone layer is about 1.80 meters thick started from the ground surface. After the sandstone layer there is a clay layer to the end of the test pit. Since the foundation's depth is 1.50m,this means that the villa was actually founded on the clay layer, not sandstone layer as stated in the geotechnical report. The clay has free swell value of about 90%. This number indicates expansiveness potential of the clay.

3.3.6.5. Corrective action

Due to presence of shallow clay layer under the foundations diagonal and horizontal cracks started to appear after completion of construction. Checking for the cracked elements performed also to ensure the safety of these elements. The swelling of the clay soil under the building caused these cracks, but the tests ensure that these elements are structurally safe. After the soil inspection, the consultant confirms that the soil has reached its maximum expansion and that means it reached its stable case and it is expected that no more swelling will happen. After ensuring that the cracks width will not increase, these cracks were filled with an appropriate sealing.

3.3.6.6. Original soil investigation scope

Two boreholes have been taken up to 10.0m depth below ground surface. According to the Egyptian code of practice for soil mechanics, design and execution of foundations (2001), the minimum number of boreholes is two for depth of 10.0m if the construction area between 100m^2 and 300 m^2 , and one extra borehole for each 300-500 m^2 for areas larger 300 m^2. Since the surface area of the building is 475m^2 which is more than 300m^2,the number of boreholes should be three (3) at least for this building.Accordingly, original soil investigation does not meet the minimum requirement of the code from the technical point of view.

3.3.6.7. Original soil investigation cost

The soil investigation cost has been estimated based on the cost of the boring for the unit length of the soil plus the machine transportation cost. The price for unit length of the boring at the time was about 35 LE/m and the machine transportation cost was (LE 500). The length of the two taken boreholes was 20m which means that the total cost of soil investigation was about (LE 1,200).

3.3.6.8. Comparing soil investigation cost typical one

According to literature survey conducted in this thesis, the typical cost values for soil investigation in buildings projects are between 0.05% and 0.20% of total project cost, or between 0.5% and 2.0% of foundations cost. While according to the Egyptian code of practice, the minimum number of boreholes should be three.Due to unavailability if the total construction cost the soil investigation,typical cost will be estimated in relation to the estimated foundation cost. Based on the foundations plan, the total cost for the foundations is calculated as following:

Table (3.6). Foundations cost for Al-Shoroukvilla

Item	Unit	Quantity	Rate*	Cost
Excavation	m^3	1035.0	11.0	11,385
Plain Concrete	m^3	133.4	260.0	34,677
Reinforced Concrete	m^3	149.7	560.0	83,835
Columns Necks	m^3	2.6	600.0	1,575
Insulation (two layers)	m^2	666.9	32.5	21,673
Back fill (Clean Sand)	m^3	751.9	12.0	9,023
Total Cost				162,167

*The rates are according to Shafei, (2000).

Typical cost values for soil investigation in buildings projects are between 0.05% and 0.20% of total project cost, or between 0.5% and 2.0% of foundations cost.

$$= (0.50\% \sim 2.00\%) x\ 162{,}167$$

$$= LE\ (\ 810 \sim 3{,}245)$$

The original soil investigation cost is (LE 1,200), so the original soil investigation cost to foundations cost= $\frac{1{,}200}{162{,}167}\ x\ 100 = 0.74\%$

This means that the cost of soil investigation is in the lower range of the typicalsoil investigation.

3.3.6.9. Rehabilitation cost for these problems

The rehabilitation cost includes three main items.

a) Cost of the new soil investigation and review the villa's design. This cost including soil visit for a consultant, one borehole, inspection for the villa cracks, review the structural design for the villa, and inspect the foundations. The cost of this item was (LE 11,000).

b) The second cost item is the cost of the testing of the structural elements. The cost of this item was (LE 3,600).

c) The third cost item is the cost of the rehabilitation of the villa cracks. The cost of this item was (LE 7600).

Thus, the total rehabilitation is (LE 22,200).

3.3.6.10. Comparing typical soil investigation with the rehabilitation cost

The typical soil investigation cost ranged between (LE 810) and (LE 3,245). While according to the Egyptian code of practice, the minimum number of boreholes should be three. The cost of the three boreholes is (LE 1,550). Then, the typical soil investigation cost is between (LE 1550) and (LE 3,245).The rehabilitation cost is (LE 22,200) which represents 14.3 times the minimum typicalsoil investigation cost and 6.8 times the maximum typicalsoil investigation cost.

3.4. SUMMARY

Based on the analyses performed in this chapter it could be concluded that the soil investigation stage in any construction project represents a major factor in the construction cost. This is not because of the cost of the soil investigation itself, but because of the consequences of any lessening or paying little attention to the process itself. The soil investigation cost is small comparing to the construction cost or even the foundation cost, but the inadequacy of the soil investigation or the inappropriate interpretation for the data of the soil investigation leads to a big increase in the construction cost and extension in the project duration. For the studied cases, Table (4.7) clarifies the results of the analyses performed to prove that the soil investigation cost is minimum comparing to the consequences that may occur due to the inadequacy of the soil investigation.

Table (3.7). Analyses results summary

Case Study No.	Currency	Typicalsoil investigation cost		Actual soil investigation cost	Extra cost	Extra cost comparing with typicalsoil investigation cost	
		Minimum	Maximum			Extra/min	Extra/max
1	LE	67,500	112,620	43,000	106,963	1.6	0.9
2	LE	670,954	5,199,892	10,000	6,842,813	10.2	1.3
3	LE	182	3550	0	155,250	853	43.7
4	DHs	22,672	90,689	9,000	1,932,075	85.2	21.3
5	YR	306,250	1,225,000	2,400,000	81,527,770	266	66
6	LE	1,550	3,245	1,200	22,200	14.3	6.8

The cost of soil investigation as a fraction of total cost may be a good first step, but the variation in the percentage must be applied. For example, for small buildings the minimum typicalsoil investigation cost might not be enough like the minimum for large buildings. In the last case study the minimum typicalsoil investigation cost does not meet the minimum requirement of the codes technical requirement. So, it is important to adopt both cost and number of tests to ensure enough soil investigation for the soil.

It should me mentioned that there is another cost to be added to the extra cost due to inadequate soil investigation. This cost is the cost of the time delay due to the problems that happened in these case studies. Due to the lack of data about these costs and the exact time for the delay in some cases, this cost has not been considered. The results show that the cost of the inadequacy of soil investigation is clear in terms of the direct cost for these problems.

CHAPTER FOUR

CONTRACTUAL AND LEGAL ASPECTS OF SOIL INVESTIGATION

4.1. INTRODUCTION

Unforeseen site conditions may have an impact on time and cost of construction project. Sometimes they may prevent the contractors form performing the contractual obligations, and other times they only make it harder or more costly to perform the contract. The contract transfer of know-how and information is critical for the successful completion of the whole operation. The extent to which such kind of information is necessary depends however not only on the project and its specification but also on the applicable law. By submitting their tenders, tenderers are usually deemed to know all relevant laws, acts and regulations that may in any way affect or govern the operations and activities covered by the tender and the resulting contract (Jaeger and Hök, 2010).

4.2. OBJECTIVE

Most of laws and codes do not specify who is responsible for taking soil investigation, but identified who is the responsible for any unforeseen site conditions. It could be concluded that the responsible for unforeseen site condition is the one who is also responsible for investigating these conditions. This chapter objective is to identify who is the responsible of the unforeseen site conditions then responsible for performing thesoil investigation, and who is the responsible of the defective construction due to any unforeseen site conditions.

4.3. RESPONSIBILITY OF UNFORESEEN SITE CONDITIONS IN LAWS

The international laws deal with the responsibility of the unforeseen site conditions in different manners. Some laws consider that the owner is the only responsible for the unforeseen site conditions that might appear on the site, so he is the one that is responsible for taking soil investigation. Other laws (most of laws) consider that the contractor is the responsible party for the unforeseen conditions that might appear on the site, because these laws consider that the contractor must have the experience to know how to deal with any unforeseen conditions. The next section provides a review of different clauses related to unforeseen site conditions in some laws.

4.3.1. Egyptian Law

The Egyptian law does not mention the responsibility of soil investigation directly, but it could be included from the following articles (These articles has been translated by joint team from Ministry of Housing and Construction and Ministry of Planting, Egypt, and Office of Housing - Agency for International development, USA, 1977)

Egyptian Civil Code: Article 147

The contract makes the law of the parties. It can be revoked or altered only by mutual consent of the parties or for reasons provided for by law.

When, however, as a result of exceptional and unpredictable events of a general character, the performance of the contractual obligation, without becoming impossible, becomes excessively onerous in such way as to threaten the debtor with exorbitant loss, the judge may according to the circumstances, and after taking into consideration the interests of both parties, reduce to reasonable limits, the obligation that has become excessive. Any agreement to the contrary is void.

Egyptian Civil Code: Article 651

The engineer and contractor are jointly and severally responsible for a period of ten years for the total or partial demolition of constructions or other permanent works erected by them, even if such destruction is due to a defect in the ground itself, and even if the master authorized the erection of the defective construction, unless, in this case, the constructions were intended by the parties to last for less than ten years.

The warranty imposed by the preceding paragraph extends to defects in constructions and erections which endanger the solidity and security of the works.

The period of ten years runs from the date of delivery of the works.

This article does not apply to the rights of action which a contractor may have against his sub-contractors.

Article 80 in Code number 98, 1989

The contractor is responsible for checking the nature of the work including any tests required for ensuring the validity of the specifications, drawings and designs. The Contractor shall give notice to the owner as soon as practicable, and will be responsible for all the specifications, drawings and designs contents as like he prepare them himself.

It could be concluded that according to the Egyptian law, the contractor is the responsible for performing any required tests to check the nature of the work. These tests comprise soil investigation. Moreover, if the owner performs the soil investigation, the contractor must check the validity of the tests performed by theowner. Because according to Article 80 in Code number 98, 1989,the contractor is responsible even if the owner perform the tests. The responsibility is including the ten years insurance that stated in the article 651 in the Egyptian civil law, where the contractor and the consultant areresponsible for the total or partial demolition of constructions or other permanent works.

4.3.2. FIDIC

FIDIC, 1999, defines the responsibilities of the owner and contractor for unforeseen site condition in Sub-clauses 4.10, 4.11 and 4.12 as following:

Sub-clauses 4.10 Site Data

The employer shall have made available to the contractor for his information, prior to the base date, all relevant data in the employer's possession on sub-surface and hydrological conditions at the site, including environmental aspects. The employer shall similarly make available to the contractor all such data which come into the employer's possession after the base date. The contractor shall be responsible for interpreting all such data.

To the extent which was practicable (taking account of cost and time), the contractor shall be deemed to have obtained all necessary information as to risks, contingencies and other circumstances which may influence or affect the tender or works. To the same extent, the contractor shall be deemed to have inspected and examined the site, its surroundings, the above data and other available information, and to have been satisfied before submitting the tender as to all relevant matters, including (without limitation):

i. The form and nature of the site, including sub-surface conditions,
ii. the hydrological and climatic conditions,
iii. the extent and nature of the work and goods necessary for the execution and completion of the works and the remedying of any defects.
iv. the laws, procedures and labour practices of the Country, and
v. the contractor's requirements for access, accommodation, facilities, personnel, power, transport, water and other services.

Sub-clauses 4.11 Sufficiency of the Accepted Contract Amount

The contractor shall be deemed to:

(a) have satisfied himself as to the correctness and sufficiency of the accepted contract amount, and
(b) have based the accepted contract amount on the data, interpretations, necessary information, inspections, examinations and satisfaction as to all relevant matters referred to in sub-clause 4.10 [site data] .

Unless otherwise stated in the contract, the accepted contract amount covers all the contractor's obligations under the contract (including those under provisional sums, if any) and all things necessary for the proper execution and completion of the works and the remedying of any defects.

Sub-clauses 4.12Unforeseeable Physical Conditions

In this sub-clause, "physical conditions" means natural physical conditions and man-made and other physical obstructions and pollutants, which the contractor encounters at the site when executing the works. Including sub-surface and hydro-logical conditions but excluding climatic conditions.

If the contractor encounters adverse physical conditions which he considers to have been unforeseeable, the contractor shall give notice to the engineer as soon as practicable.
This notice shall describe the physical conditions, so that they can be inspected by the engineer, and shall set out the reasons why the contractor considers them to be unforeseeable. The contractor shall continue executing the works, using such proper and reasonable

measures as are appropriate for the physical conditions, and shall comply with any instructions which the engineer may give. If an instruction constitutes a variation shall apply.
If and to the extent that the contractor encounters physical conditions which are unforeseeable, gives such a notice, and suffers delay and/or incurs cost due to these conditions, the contractor shall be entitled subject to:

(a) an extension of time for any such delay, if completion is or will be delayed, and
(b) payment of any such cost, which shall be included in the contract price.

After receiving such notice and inspecting and/or investigating these physical conditions, the engineer shall proceed to agree or determine (i) whether and (if so) to what extent these physical conditions were unforeseeable, and (ii) the matters described in sub-paragraphs (a) and (b) above related to this extent.

However, before additional cost is finally agreed or determined under sub-paragraph (ii), the engineer may also review whether other physical conditions in similar parts of the works (if any) were more favorable than could reasonably have been foreseen when the contractor submitted the tender. If and to the extent that these more favourable conditions were encountered, the engineer may proceed in agree or determine the reductions in cost which were due to these conditions, which may be included (as deductions) in the contract price and payment certificates. However, the net effect of all adjustments under sub-paragraph (b) and all these reductions, for all the physical conditions encountered in similar parts of the works, shall not result in a net reduction in the contract price.
The engineer may take account of any evidence of the physical conditions foreseen by the contractor when submitting the tender, which may be made available by the contractor, but shall not be bounded by any such evidence.

According to sub-clause 4.12 that if the contractor encounters adverse physical conditions he shall continue working, using proper and reasonable measures as are appropriate for the physical conditions. Only if and to the extent that he encounters unforeseeable physical conditions will he be entitled to an extension of time for completion and payment of additional cost (Jaeger and Hök, 2009).

4.3.3. French Law

According to the French Code of Construction and Housing, the responsibility for unforeseeable physical conditions related to the ground shall be taken by the contractor, who has a general duty of inspecting the site while working in the so-called protected area. Therefore, under French consumer law the employer doesn't have to bear additional costs related to unforeseeable physical conditions of the soil.

4.3.4. German Law

According to the German law, the Employer bears the risk of unforeseen subsoil conditions, which may have an impact on the understanding of sub-clauses 4.10, 4.11 and 4.12 in FIDIC. German law it is not strictly forbidden to shift the soil risk to the contractor and that the extent to which this risk becomes shifted to the contractor is fairly limited to foreseeable risk. All of the unforeseeable risks as to the physical conditions of the site are borne by the employer. Finally it must be doubted that Section 645 German Civil Code shifts the risk for the whole of the physical conditions to the employer. In fact the employer's risk comprises any deviation of the building ground from the composition of the ground to be expected and described in detail in the specifications (Rosener and Dorner, 2005)

4.3.5. Italian Law

Italian law is more specified in dealing with the unforeseen conditions. Italian Law stipulates that in the case of unforeseen events, the project cost for time and materials must exceed 10% of the original contract price before the contractor has a right to ask for revisions to the contract including time and price (Italian Civil Code, Article no. 1664).

4.3.6. New Zealand Law

New Zealand Standards NZS 3910:2003 defines the responsibility of soil investigation as in the following clauses:

Clause 9.5

If during the contract the contractor encounters on the site physical conditions which could not reasonably have been foreseen when tendering by an experienced contractor and which will substantially increase its costs, the effect of such conditions shall be treated as if it was a Variation.

Clause 5.1.6 goes further by providing:

The principal warrants that it has made available to the contractor before the submission of the contractor's tender all information of which it is aware, which has been obtained by or on behalf of the principal or engineer for the purposes of the contract, on the nature of the physical conditions relevant to the contract works. The principal makes no warranty as to the sufficiency or accuracy of such information. The contractor shall be responsible for the interpretation of all such information for the purposes of the contract works.

This clause appears to try to have it both ways by dealing with the lack of a common law duty to disclose, but trying to avoid any liability for misrepresentation. It fails on both counts. While it contains a warranty that the employer has provided all the information it has, it provides no incentive for the employer to carry out sufficient investigations to identify any risks particularly relevant to the project (Walton, 2007).

4.3.7. Malaysian law

The Malaysian law stated that, the contractor shall be deemed to have inspected and examined the site and its surroundings and to have satisfied himself before submitting his tender as to the nature of the ground and sub-soil, the form and nature of the site, the extent and nature of the work, materials and goods necessary for the completion of the works, the means of communication with and access to the site, the accommodation he may require and in general to haveobtained for himself all necessary information as to risks contingencies and all circumstance influencing and affecting his tender. Any information or document given or forwarded by the government to the contractor shall not relieve the contractor of his obligations under the provisions of this clause. The government gives no warranty for the information or document either as to the accuracy or sufficiency or as to how thesame should be interpreted or otherwise howsoever and the contractor shall make use of and interpret the same entirely on his own risk.

For a building or civil engineering contract, soil and sub-soil information is usually needed. Thus a site investigation is usually necessary, which typically includes boreholes and other subsurface investigations. As to such kind of information great care has to be taken, because except in Germany and some other civil law countries, at common law the risk of unforeseen site conditions is usually borne by the contractor. Failure to comply with the pre-tender or pre-contract obligation to investigate and survey the site may lead to a considerable pricing risk, if and when common law is the proper law of the contract. Standard forms which originate from common law countries thus normally comprise detailed provisions on the allocation of the soil risk (Jaeger and Hök, 2010).

Egyptian law is clear about bearing the contractor the whole responsibility of any unforeseen conditions. There is no argument about the contractor responsibility of any unforeseen conditions and then by default the soil investigation. Even though the Egyptian law makes the consultant jointly with the contractor responsible for any defective construction, but according to the code number 89, 1989 the contractor is responsible for any required test to check the work nature even if the owner or the consultant made these.

Most of the international laws coincide with Egyptian law in bearing the contractor the whole responsibility for the unforeseen site condition, but with difference in the contractor right to ask for compensation. International laws can be used to improve the Egyptian law in this point. Italian law has a very interesting point. Italian law is attaching the contractor right of asking for any compensation by the effect of the unforeseen site conditions. The project cost and/or time must exceed 10% of the contract price and/or duration before the contractor has a right to ask for revisions to the contract price and/or duration. Another point that can be used which is available in FIDIC and New Zealand law. This point is giving the contractor the right of asking for a variation in case of finding unforeseen site conditions. By this variation, the contractor has the right of asking for extra cost and duration if he faced unforeseen site conditions.

It should be noted that right of asking for variation is limited for the case of appearing of unforeseen site condition which couldn't be expected by an expert contractor. This means if the unforeseen site conditions appear due to lack of tests or lessening of the soil investigation cost, the contractor will bear the whole consequences. So, the contractor is responsible for performing a proper soil investigation to get the right of asking for a variation in case of finding unforeseen site conditions.

It should mention that laws give the contractor the right of checking the subsurface conditions himself before submitting his tender. But, the raised question is that whether the contractor is willing to pay the soil investigation expenses without any guarantees to perform this project. Actually, it might seems cheaper to handle certain risk of facing unforeseen site conditions that to pay soil investigation cost to all projects that the contractor will submit a proposal to perform its work. An interesting way of dealing with this matter has been made in many projects. The solution for this problem comes by sharing the pre-tender soil investigation cost by all contractors interested in submitting proposals. The winner contractor may or may not return the soil investigation expenses to other contractors. This will be based on the agreement of these contractors. This method is more applicable in large projects.

4.4. CONTRACTUAL ASPECTS OF SOILINVESTIGATIONS

The contract is the main reference in case of any disputes between the contract parties. Article 147 of the Egyptian Civil Code, states: "The contract makes the law of the parties”. So, it is important toadd clause(s)to the construction contracts in a way that ensure the responsibility of the soil investigations. This clause(s) should comply with Egyptian law. If any clause in the contract contradicts with the Egyptian law it will be invalid. As mentioned in the section 5.2. of this chapter that the laws do not specify who is responsible for making the soil investigation but mentioned who is responsible for any problems during or after construction due to any unforeseen conditions. In the Egyptian law, the contractor is responsible for checking the nature of the work including any tests required for ensuring the validity of the specifications, drawings and designs. The soil investigation test can be considered as one of the required tests to know the nature of the work. The Egyptian law makes the contractor and the consultant responsible for any defects due to any unforeseen condition.Furthermore, the contractor and the consultant are responsible even if the owner asks them to do the work in a way that makes these problems happened. The owner and the contractor or the owner and the consultant are not obligated to follow certain type of contracts or to write specific clauses in their contracts. There are a number of ministerial decrees that suggested comprehensive contracts between the owner and the contractor, and the owner and the consultant. These contracts are guiding contracts, and the parties have the option to follow them or choosing their own contracts. The article in these contracts regarding the soil investigation or unforeseen site conditions are as following:

It is mentioned in the Ministerial decree number 222 for the year 1994 about the general conditions for the construction contracts the following:

- Article 43. Boreholes and investigations: if the engineer (The consultant) or the contractor found that more soil investigation is required, then the engineer should mandate the contractor to make the required soil investigations. The extra soil investigation is to be considered as an extra work except if this work has been listed in the Bill of Quantities.
- Sub-article 24/2. Site inspection and preview: if the contractor faced any natural or artificial obstacles which may affect the project time and duration, he should inform the engineer (consultant). If the consultant is convinced that these conditions could not be discovered by an expert contractor, he should review the contractor requests to determine the extra cost that the contractor paid to face any circumstances that were not expected during tendering period. The owner should pay these expenses, and the contractor should be given an extra time to overcome these obstacles.

In the guiding contract for studies and designing, it is mentioned in the addendum 2 of the ministerial decree number 221 for the year 1994, it is one on the consultant scope of work to supervise the soil inspection and experiments, and study and evaluate the soil reports.

In the guiding contract fordesign and execution (by the owner funding), the ministerial decree number 246 for the year 1999, article number 4-11 under title “under-ground unexpected conditions”, the following:

- If the contractor faced any under-ground unexpected conditions and he thinks that these conditions could not be discovered by an experienced contractor, the contractor should inform the owner to inspect these conditions. After inspection and exploration, the owner should agree on or decide to:
    1. What is the time extension is the contractor deserve?
    2. What is the extra cost that should be added to the contract price due to these conditions?

After deciding, the owner should inform the contractor what is his decision.

It is obvious that the guiding decrees are compatible with the Egyptian law. In both the contractor is responsible for making the soil investigation, while the consultant is the one who is responsible for supervising the soil investigations. Consultant and contractor both are responsible for making a decision if more soil investigation is required. The only difference between the Egyptian law and these ministerial decrees is that theministerial decrees give the contractor the right of asking for compensation in case on facing unforeseen site conditions. But, the owner and the consultant have the upper hand of deciding whether if the contractor deserving to be paid for overcoming these conditions or not. On the other hand, the contractor and the consultant are both responsible for any consequences for the unforeseen site condition. This makes sense because the owner usually does not have experience about the right procedures to construct his structure. But such conditions make the contractor constrained to the consultant and owner willing to pay. To measure the engineers' opinion if a certain clause(s) must be added to the construction contracts to handle to soil investigation issue, a questionnaire survey has been performed. The responses will be analyzed in section (5.5) of this chapter.

Thus the contractor should make the contract with the attempt to minimize the risk as much as possible. Usually a clause will be adopted which defines the term unforeseeable as anything that could not reasonably been foreseen at tender stage by an experienced contractor. The contract should also provide any necessary additional work due to soil obstructions and unforeseen physical conditions. The report on soil investigation, that the employer has usually commissioned to progress basic feasibility studies and initial outline design will be issued to (or otherwise made available for use by) the tenderers, preferably in its original form, in order to inform the tenderers about the soil conditions. Most employers will consider it to be unwise for them to take responsibility for the report by including it within the Tender Dossier. Thus such reports are often part of the "information documents" made available to the tenderers. Usually any tender enquiry documentation includes exclusion clauses stating that the employer accepts no responsibility for the accuracy of such investigation reports. It is also common and good practice from the point of view of an employer for the documentation to include the advice to the tenderers to carry out their own site survey and investigations (Jaeger and Hök, 2010).

4.5. THE QUESTIONNAIRE SURVEY

To measure the engineers' opinion about the efficiency of the current soil investigation procedures and regulation, and their opinion about reducing the imperfection (if there is any) of these procedures, a questionnaire survey has been conducted. The main purpose of this questionnaire is to know the effect of an inadequate soil investigation, to what degree is the ongoing soil investigation system effective, and who is the responsible of the soil investigation from the engineers' point of view. Another purpose for this questionnaire is to know how the issue of the soil investigation can be effectively handled in the Egyptian law and construction contracts. The questionnaire starts by asking the respondents about their names, occupation and companies that they are working. After that there is a small introduction about the research and the researcher. General information has been asked to the respondents about their companies experience and classification. The second part of the questionnaire starts by an introduction about the subject under study,then summary about theresponsibilityof the unforeseen site conditions in the international laws. This part gives the respondents brief information about the issue under study. The last part of the questionnaire consists of twelve questions. The first eight questions are multiple choice questions mainly about the unforeseen site conditions risk, likely of happening, frequency of happening and consequences. The other four questions are asking the respondents to explain their answers in the previous questions and also asking them if they have any suggestions to improve the unforeseen site conditions responsibility in the Egyptian laws and construction contracts respectively. The questionnaire main questions are as following:

1. How do you think the risk of unforeseen soil investigation?

   (a) V. High ( ) (b) High ( ) (c) Medium( )

   (d) Low ( ) (e) V. Low ( )

2. Is the Egyptian code of practice deals properly with soil investigation from the technical point of view?

   (a) Yes ( ) (b) No ( )

3. Did the soil investigation made properly in the projects you have worked on?

   (a) Always ( ) (b) Often ( )

   (c) Sometimes ( ) (d) Never ( )

4. How many times have you found the soil interpretation identical with the soil investigation report?

   (a) Always ( ) (b) Often ( )

   (c) Sometimes ( ) (d) Never ( )

5. How often did you face unforeseen site conditions?

   (a) Always ( ) (b) Often ( )

   (c) Sometimes ( ) (d) Never ( )

6. What is the frequency of occurrence of increasing the cost of a project more than its plannedvalue as a result of facing unforeseen site conditions during construction?

   (a) Always ( ) (b) Often ( )

   (c) Sometimes ( ) (e) Never ( )

7. What is the frequency of occurrence of increasing the duration of a project more than its plannedvalue as a result of facing unforeseen site conditions during construction

   (a) Always ( ) (b) Often ( )

   (c) Sometimes ( ) (e) Never ( )

8. Based on your experience, who should take the responsibility of the unforeseen site conditions?

   (a) The owner ( ) (b) The contractor ( )

   (c) Sharing the responsibility somehow between them ( )

9. What was the reason for your answer for question (8)?

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

10. If your answer in question (8) was sharing the unforeseen conditions responsibility between the owner and contractor, what is the sharing method that you suppose it would be appropriate?

    ……………………………………………………………………………………………………

    ……………………………………………………………………………………………………

11. What are your suggestions for modifying the Egyptian law to improve it in the field of soil investigation?

    ……………………………………………………………………………………………………

    ……………………………………………………………………………………………………

12. In your opinion, what are the clauses to be added to the contracts to cover the soil investigation responsibility?

    ……………………………………………………………………………………………………

    ……………………………………………………………………………………………………

The questionnaire has been given to more than 50 engineers. Only 31 of them have responded (List of the respondents are shown in Appendix 1). The respondents self-experience and companies' experiences are different. Most of the engineers have an experience more than 5 years in the construction field. Some of them have experience more than 15 years. Three professors responded to the questionnaire. It is also noted that most of the companies that the respondents worked in have experience for more than 15 years in the construction field. So, there is high diversity in the respondents self, and companies experiences (Sample of the questionnaire responses are shown in Appendix 1).

The first question asks about the risk of the unforeseen site conditions. The purpose of this question is to measurethe risk of the unforeseen site conditions from the engineers' point of view.

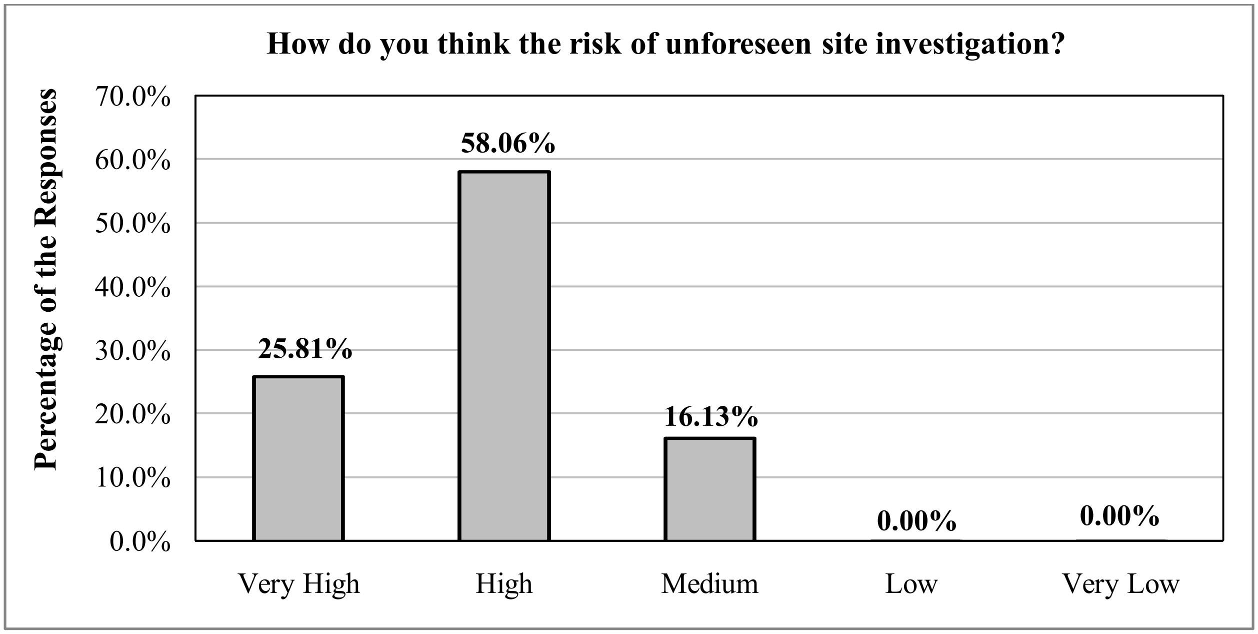


Figure (4.1) Response of the questionnaire's first question

According to Fig.(4.1), the responses show that most (83.87 %) of the engineers think that the unforeseen site conditions risk is high or very high. None of the respondents think that the risk of the unforeseen site conditions is low or very low. Only 16.13% of the respondents identified the risk as medium risk. Accordingly, the risk of the unforeseen site conditions can be considered mainly as high to very high risk.

The second question is about the validity of the Egyptian code of practice in the field of geotechnical investigations. Some of the asked engineers (10% of them) did not respond to this question, maybe because they never dealt directly with the Egyptian code of practice, so they prefer to skip this question. Figure(4.2) shows the percentage of the engineers who respond to the question.

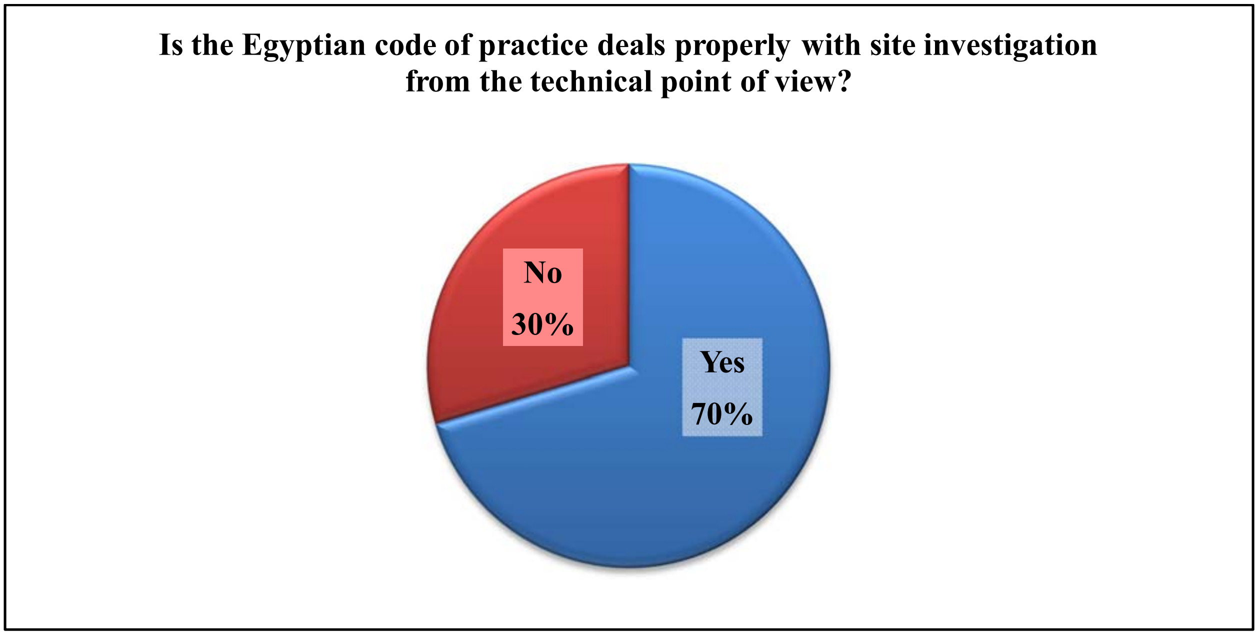


Figure (4.2) Responses of the questionnaire's second question

The responses for the second question show that 70.0% of the individual who dealt with the Egyptian code considered that the Egyptian code is enough from the practical side to avoid the high risk of the unforeseen site investigation. It is obvious that according to their opinions, if the recommendations of the Egyptian code have been followed, the risk of the unforeseen site investigation can be controlled.

The third question asks if the soil investigation were usually made properly in the projects that the asked engineers have worked on. This question goal is to ask about the application of the code in the field. If the soil investigation code recommended procedures are properly followed or not in the project they worked on. Figure(4.3) shows the responses for this question.

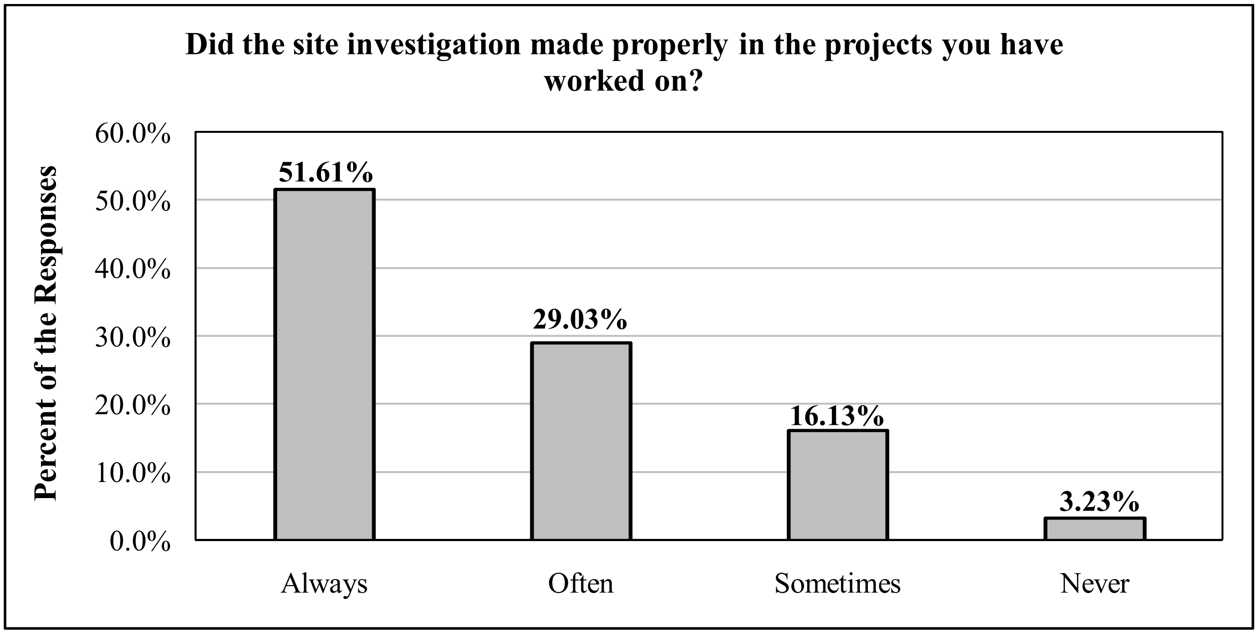


Figure (4.3) Responses of the questionnaire's third question

The responses for the third question showed that 51.61% of the engineers who were asked considered that the soil investigation is always made according to the projects specifications and Egyptian code. Only 19.36% of the responses results went to the idea that the soil investigation is sometimes or never made properly in the project that they have worked in. This question responses show that since the code requirement force the contractor to perform the soil investigation according to specific regulation, the contractor tend to follow these requirements. The contractor is obligated to do it according to the code, but if it is not enough, there is no obligation to extend the scope of the soil investigation.

The fourth question is about how many times have the engineers found the soil interpretation identical to the soil investigation reports. This question is to support the third question idea, where if the soil investigation was properly made, the soil interpretation must be as in the soil interpretation report. Figure(4.4) shows the responses for this question.

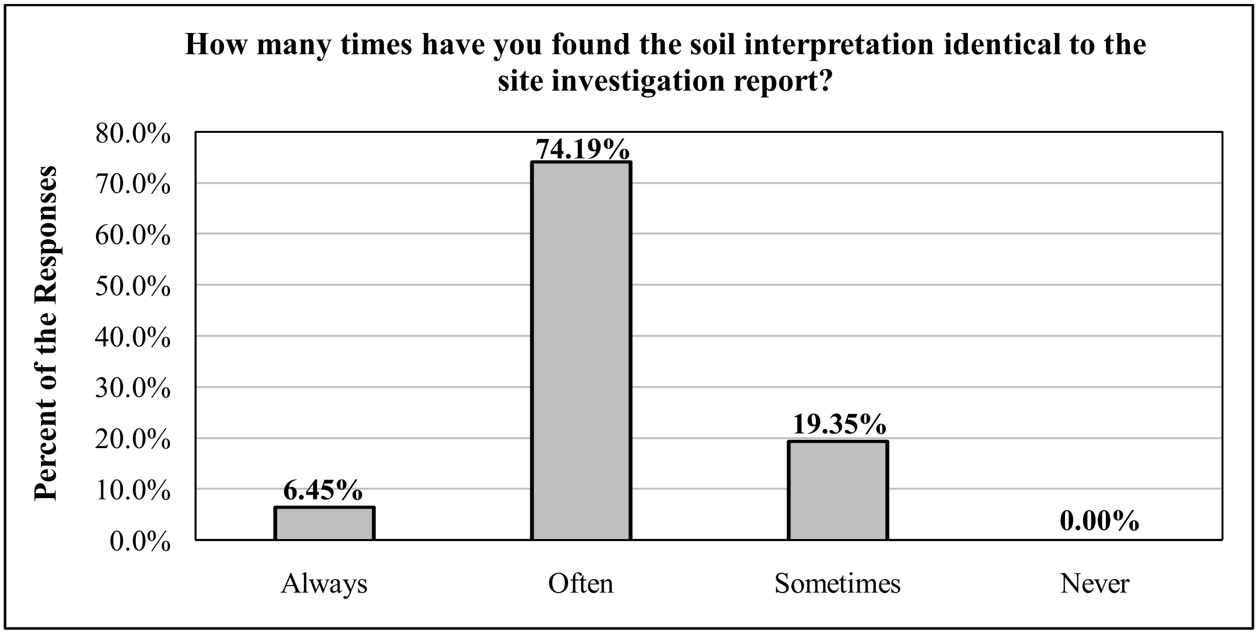


Figure (4.4) Responses of the questionnaire's fourth question

Figure (4.4) above shows that 74.19% of the responses are with the idea of that the soil interpretation is often identical with soil investigation report. This means that there are cases that they face where soil interpretation is differing than the soil investigation report. It should be noted that the two extreme opinion almost disappeared, where there is only 6.45% of the engineers noted that the soil interpretation is always identical with the soil investigationreport; While no one chose the opinion that means they never faced any case where the soil interpretation report does represent the actual site. Another note is that the percentage of the responses that support the idea of that the soil investigation is sometimes or never been made properly in the project is the same as the percentage of the response that support the idea that there are sometimes only soil interpretation is identical with the soil investigationreport. This leads to a conclusion that if the soil investigation procedures not followed carefully, the soil interpretation may be different than the soil investigationreport.

The fifth question is about how many times have the engineers face an unforeseen soil conditions. This question is considered as more details about the forth question. This complementary question asks if the engineers faced unpredictable site conditions that might lead to delay the work, or more cost.

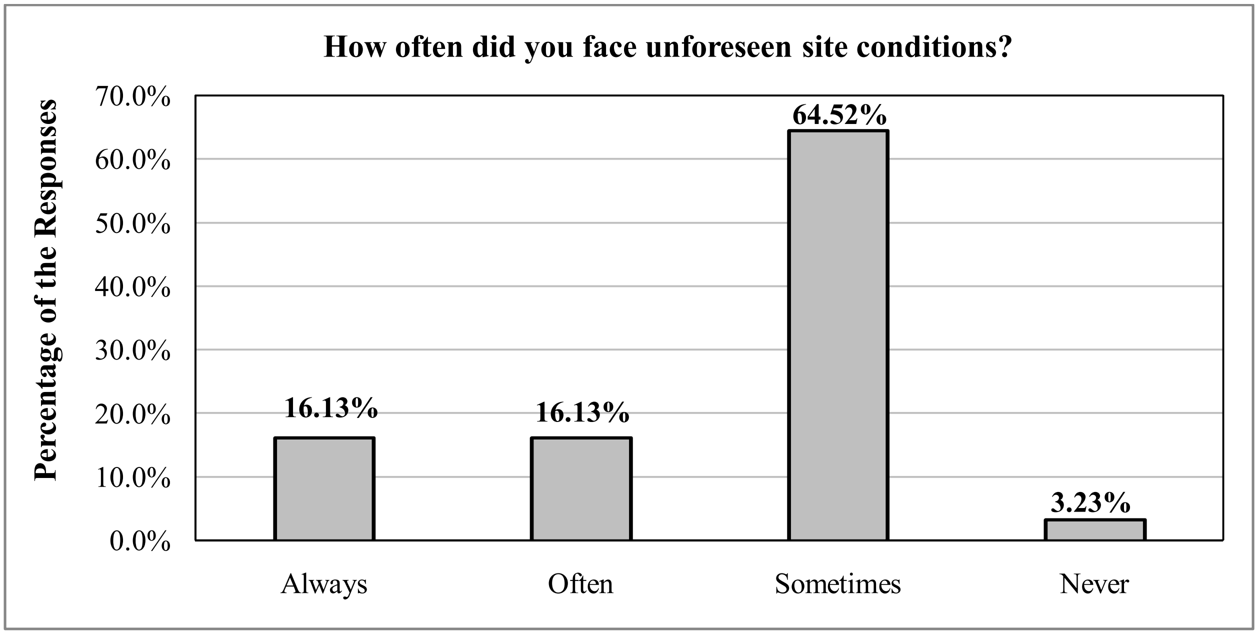


Figure (4.5) Responses of the questionnaire's fifth question

Figure (4.5) shows that 64.52% of the responderssupported that there are sometimes the engineers are facing unforeseen site conditions. This means that there are cases that they face where soil interpretation differs than the soil interpretation report. The responses that goes with that they are always or often have faced unforeseen site condition represent 32.26% of the responses. A conclusion could be reach, this conclusion is that the percentage of the projects that faced an unforeseen site conditions is at least 32.0%.

The sixth and seventh questions are about the frequency of occurrence for increasing the cost and time of project more than their planned values due to unforeseen site conditions during construction. These questions are devoted to the main purpose of this thesis. These questions help in knowing the effect of the inadequate soil investigations in the cost and time of the constructionprojects. Figures (4.6) and (4.7) show the responses for this question.

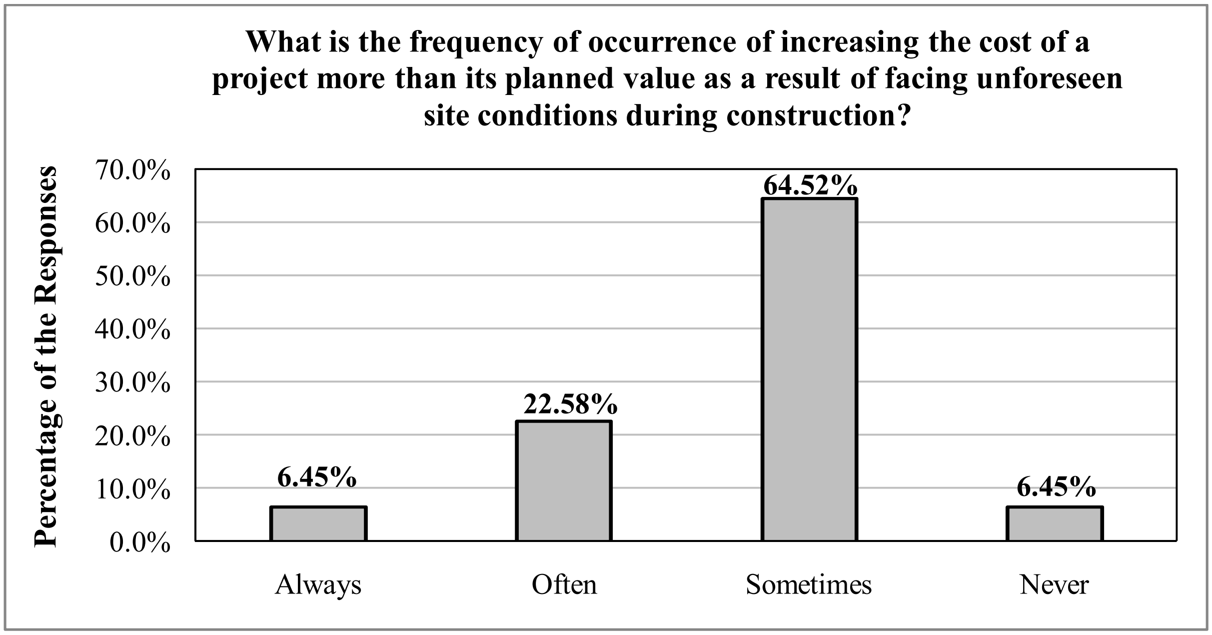


Figure (4.6) Responses of the questionnaire's sixth question

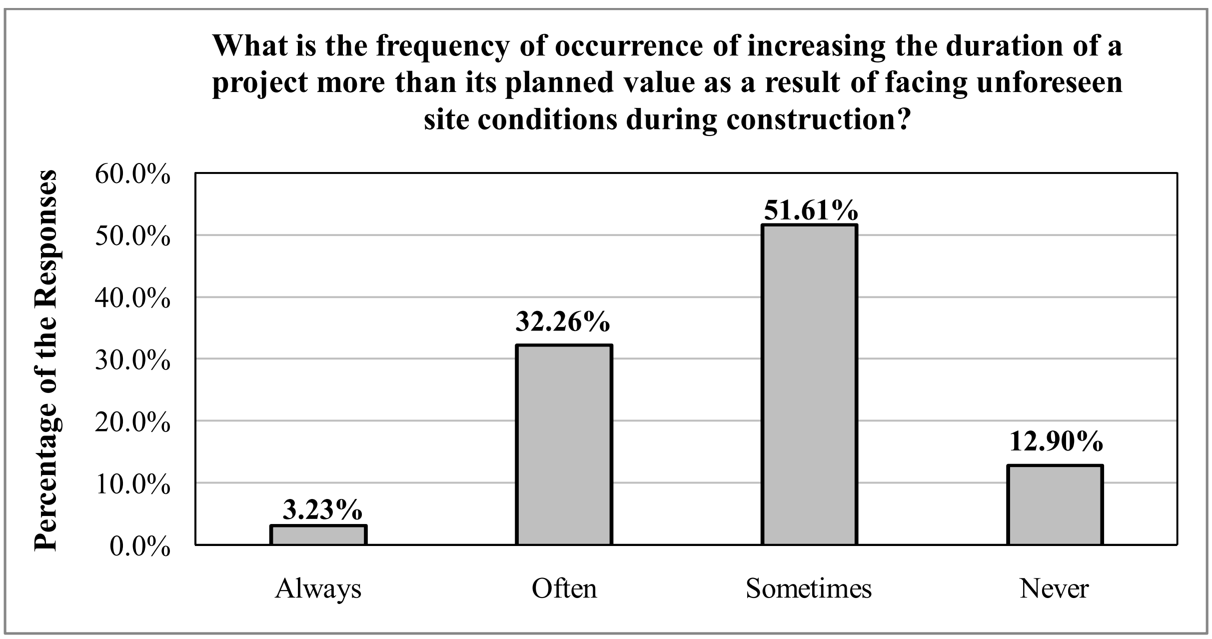


Figure (4.7) Responses of the questionnaire's seventh question

The two responses almost have the same trend, with difference in the percentages for each item. The major responses for both questions are for that it is sometimes or often the projects'cost and/or timeexceeds the planned values due to facing unforeseen site conditions.

More than half of the responses for the fifth questions and about half of the responses for the sixth questions indicated that this sometimes happened. It could be concluded that the likely of thatthe project cost and/or timeexceed their planned values due to unforeseen site conditions during construction process between 25% and 75%. It should be noted that the percentage of the engineers who never face cases where cost overrun is half of the percentage of the engineers who never faced cases where project duration has been extended due to unforeseen site conditions during construction. The same conclusion can be reached, the percentage of the engineers who always face cases where cost overrun is twice of the percentage of the engineers who never faced cases where project duration has been extended due to unforeseen site conditions during construction. This means that it is more common for the cost to be increased more than duration to be extended due to the unforeseen site conditions.

The eighth question is about the engineers' opinion about who should take the responsibility of the unforeseen site conditions. The responses should be one of three answers: Owner, Contractor or sharing the responsibility between them both. Figure(4.8) shows the responses for this question.

About two-thirds of the responses were devoted to sharing the responsibility between the owner and contractor. In the remaining one-third of the responses are the engineers who support the idea that the contractor should take the responsibility are more than twice the engineers who support the idea that the owner should take the responsibility. For further analyses another point of view has been followed. Figure(4.9) shows the percentage of the engineers in another way. Since the questionnaire has been filled by two types of engineers,the two types of engineers are those who work with an owner or a consultant, and the other type is the engineers who work for a contractor. Analysis has been made to know which type of engineer adopted which answer of the question

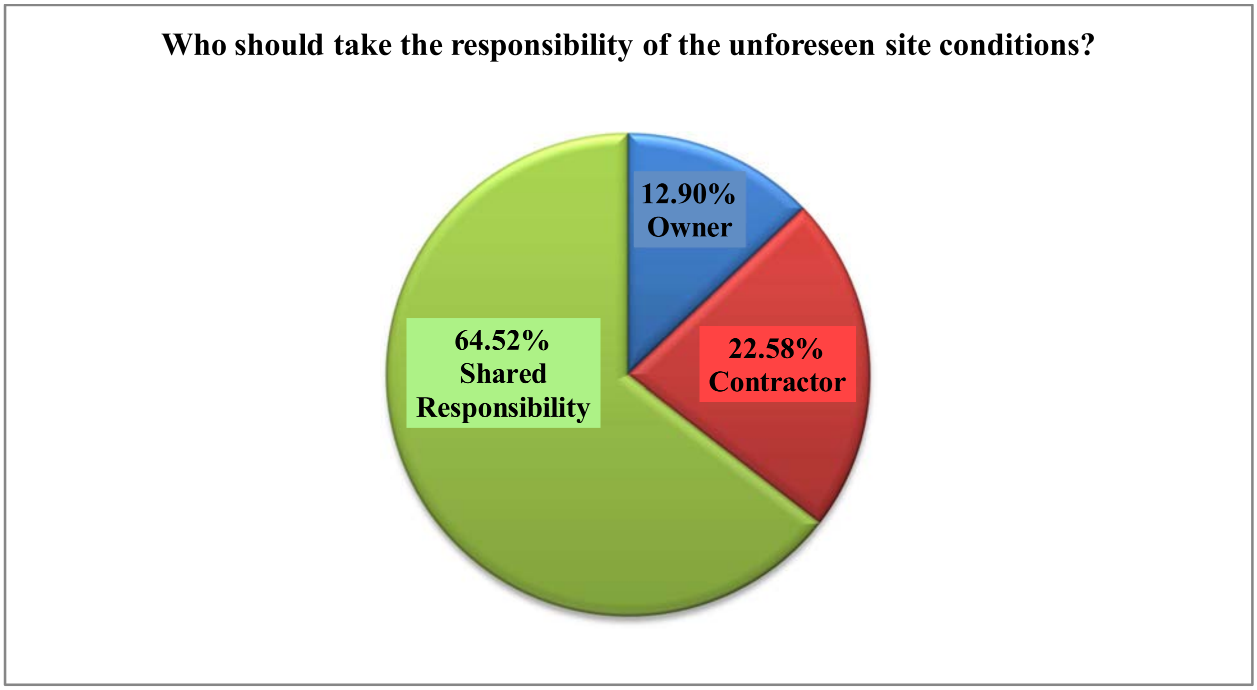


Figure (4.8) Responses of the questionnaire's eighth question (First Analysis Method)

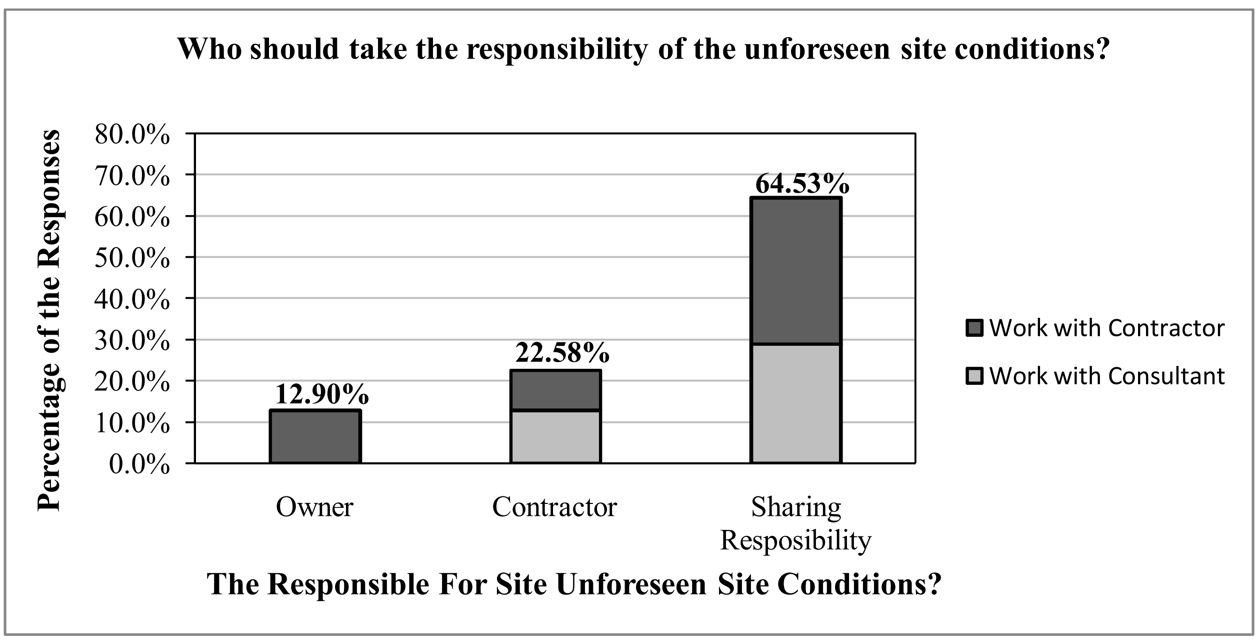


Figure (4.9) Responses of the questionnaire's eighth question (Second Analysis Method)

The result of this analysis shows that all of the engineers who choose that the owner should take the responsibility of the unforeseen site conditions are working for a contractor or contracting companies. While most of the engineers who choose that the contractor should take the responsibility of the unforeseen site conditions are working for an owner or a consultant. The remaining engineers supported the idea in which the responsibility has to be shared between the owner and the contractor. It is noted that everyone try to avoid the responsibility or at least share it with others. There are some engineers working with contractors or contracting companies chose that the contractor should take the responsibility. This might have come from the idea that they know that the Egyptian law makes the contractor bear the responsibility.

The ninth question asked the respondents to explain why they chose their response in the previous question. The respondents defense their choices as following:

a. Respondents who chose that the owner is responsible for the unforeseen site conditions supported their opinions by the following ideas.

    - The owner should make the soil investigation prior to tendering stage.
    - The owner should pay to specialist soil investigation contractor to make the soil investigation.
    - The owner should notify the contractor about any condition in the site to avoid the unforeseen site conditions.
    - Consultant represents the owner on the site, so consultant should recommend a proper soil investigation. If the contractor does not make a proper soil investigation, the consultant should notify the owner to make a decision.

b. Respondents who chose that the contractor is responsible for the unforeseen site conditions supported their opinions by the following ideas.

    - Contractor should take into consideration the cost of a proper soil investigation before submitting the proposal. This procedure should be taken into consideration to avoid cost overrun due to the unforeseen site conditions.

- The contractor should make a proper soil investigation before starting project construction.
- Usually the owner does not know details regarding the projects construction requirements. The contractor is the one who should have the experience about what is required for construction.
- Contractor is the one who will face the unforeseen site conditions.
- Contractor should convince the owner to spend more money in soil investigation if it is necessary.

c. Respondents who chose that the owner and contractor shared the responsibility for the unforeseen site conditions supported their opinions by the following ideas:

- Owner should guarantee the availability of all the data concerning construction site before tendering process. On the other hand, the contractor should investigate the site and its surroundings until being satisfied before submitting his proposal.
- Contractor should investigate the soil to evaluate the suitability of the site for the proposed structure. Contractor should inform the owner about any obstacles that might affect the project because the owner has the power of taking decisions.
- Owner should hire a specialist soil investigation contractor to make the soil investigation. While the contractor should confirm the validity of the given data.
- Contractor should make a confirmation soil investigation to check the validity of the given data from the owner. If the confirmation soilinvestigation contradicts with the data from the owner, the contractor has to request an additional cost for a proper soil investigation.
- Owner is always looking for reducing the project cost. While the contractor tends to maximize the cost to get more profit. So, it has to be agreed between both owner and contractor what is the size of the required soil investigation.

- Contractor does not has the authority of taking the decision of changing the soil investigation scope except if the owner gives the contractor this authority.
- Owner should add a clause to the contract about the responsibility of the soil investigation, and the contractor should fulfill these clauses.
- Owner should obligate the contractor to make a proper soil investigation, and the contractor takes the responsibility only in this case.

It is obvious that each of the owner and contractor have a specific responsibility. The owner has the responsibility of providing the contractor by all available data regarding the site conditions. A proper preliminary soil investigation should be madeby the owner to give the contractor awareness about what might appear in the site. The owner may shift the responsibility of the soil investigation to the contractor to avoid the responsibility of the unexpected site conditions or if there is no available data regarding the site conditions. In case of owner shifted the responsibility to the contractor, a proper payment should be added to the contract cost to make the soil investigation. On the other hand, a properpreliminarysoil investigation helps the contractor to prepare his proposal in a better base. The risk of facing unforeseen site conditions can be reduced by making the preliminary soil investigations.

The tenth question was about the way of sharing the responsibility of the unforeseen site conditions. This question is asked for the respondents who answered the previous question by the owner and contractor share the responsibility of any unforeseen site conditions. The main ideas of their responses are as following:

- The soil investigation cost must be paid equally by both the owner and the contractor.
- Owner should make a preliminary soil investigation. A confirmation soil investigation should be made by the contractor before commencing project construction.
- The sharing comes by periodic meetings between the owner and the contractor to discuss the project problems.

- Owner should take the responsibility of any inadequate data that should have been submitted before to the contractor. Contractor takes the responsibility of any inadequate procedures regarding the soil investigation.

- The owner should make proper soil investigation for the proposed structure. The owner also should ask the contractor to make proper tests in trustworthy labs.

- Owner should hire a specialist soil investigation contractor to make the soil investigation. Contractor also should hire another specialist soil investigation contractor to make additional soil investigation. Comparison between both soil investigation results should be made by the contractor before pursuing the construction.

- The method of sharing should be agreed between the owner and the contractor, and should be added as a clause in the construction contract.

- The project specifications should illustrate the necessity of the soil investigation, and the responsibility of both the owner and the contractor sharing method.

- The contractor should be obligated to overcome all the unforeseen site conditions without extending the construction period. The owner should pay all the expenses that the contractor spend to overcome these conditions.

- The owner should be willing to pay and request. The contractor should be willing to do the soil investigation properly and professionally.

The method of sharing the responsibility of the unforeseen site conditions between the owner and the contractor must not be solid. The method of sharing must be depending on the type of the project, the owner, the consultant and the contractor experiences in the field of soil investigation. The owner and contractor should agree who is responsible for overcoming the unforeseen site conditions. There are many ways of sharing between taking the whole responsibility and cost by the owner to shifting the whole responsibility and cost to the contractor.

The eleventh question was about the suggestions that might improve the Egyptian law in the field of unforeseen site conditions. Some of the responses are matching the Egyptian law. However, the main ideas are listed below whether they are matching the Egyptian law or not. The main ideas of their responses are as following:

- The law should obligate the contractor to make a confirmation soil investigation even if the owner made a soil investigation prior to tendering process.
- The law should force the owner and contractor to hire specialists in the soil investigation to make the soil investigation. The soil investigation report should be issued from a trustworthy contractor.
- It should be mentioned in the law that the owner has to make soil investigation before starting the project. The expenses of this soil investigation might be paid by the contractor later. While the expenses of any consequences of the inadequate soil investigation should by paid equally by both the owner and the contractor.
- It cannot be covered in the law. The soil investigation depends on the project type, site experience, and site conditions. The minimum limits which are mentioned in the Egyptian code of practice is enough.
- The owner must be obligated to make the soil investigation under supervision of a trustworthy consultant. The consultant should take the whole responsibility of the soil investigation and any consequences from the inadequacy of the soil investigation.
- This is a technical matter and cannot be covered by law. The construction contract and the project specifications should be devoted to reach a good quality of the executed work and should give time for good investigation.

The recommendations for the Egyptian law modifications in general tend to obligate the owner or contractor to make asoil investigation. In the Egyptian law it is mentioned that "The engineer and contractor are jointly and severally responsible for a period of ten years for the total or partial demolition of constructions or other permanent works erected by them, even if such failure is due to a defect in the ground itself, and even if the master authorized the erection of the defective construction, unless, in this case, the constructions were intended by the parties to last for less than ten years.”. Also in another article of the Egyptian law it is mentioned that “The contractor is responsible for checking the nature of the work including any tests required for ensuring the validity of the specifications, drawings and designs, and will be responsible for all its contents as like he prepare them himself”. This means that the contractor is the one who is responsible for making the soil investigation. While the consultant and the contractor share the responsibility of any consequences due to inadequate soil investigation. It is not required from the owner to give the contractor any information regarding the site conditions. The law should obligate the owner to make a preliminary soil investigation. It is good way to give the contractor an indication about to what extend the confirmation soil investigation should perform.

The twelfth question was about suggested clauses that might be added to the construction contracts to cover the responsibility of the unforeseen site conditions. The responses were mainly about adding clauses to the construction contracts about the following matters:

- Qualifications of contractors who are going to do the soil investigation should be identified.
- The contractor responsibility should be decided based on the project type.
- The contractor is the only responsible for any obstacles in the site.
- A severe punishment should be applied on the negligent.
- If the unforeseen site conditions were because of inefficiency of the soil investigation, the extra cost should be shared equally between the owner and the contractor. Otherwise, the extra cost should be paid by thenegligent.
- The soil investigation should be carried out before starting the project. A survey for the project surrounding condition should be taken to considerations.
- The construction contract should specify who is the responsible for the unforeseen site conditions.

- The owner should supply the contractor by a recent soil investigation report. The contractor should take a confirmation soil investigation. The consultant should approve the confirmation soil investigation. The owner should pay the extra cost if the confirmation soil investigation is different than the owner soil investigation report.
- Any extra works due to unforeseen site conditions should be approved and paid by the owner, unless if the contractor hides any technical information to get more profit.
- If the soil in the site found different than the owner soil investigation report, the owner and contractor should agree about who should pay the extra cost and the required extension in the project duration due to this difference.
- The risk sharing percentage due to the unforeseen site conditions should be agreed between the owner and contractor.

There is no obligation that may force the owner, the contractor, or the consultant to write certain clauses in the contract between them. Most of the responses for this question supported the idea that it is very important to specify responsibility of unforeseen site conditions in the construction contracts. Unfortunately it does not worth to specify who is the responsible because the Egyptian law is firm in specifying who is the responsible for any defects due to the unforeseen site conditions regardless the responsible in the contract. It may be worth to specify who should pay to overcome any expenses due to the appearing of any unforeseen site conditions. Moreover, it is more applicable to specify who is the responsible for making the soil investigation, or who is responsible for paying the cost of the soil investigation.

4.6. SUMMARY

The international laws arediffering in specifying who is responsible for the unforeseen site conditions. Some of the laws made the owner responsible for any consequences happened due to the unforeseen site conditions, but most of the laws made the contractor the responsible one. The Egyptian law was clear in the article 80 of the Code number 98, 1989 which contains "The contractor is responsible for checking the nature of the work including any tests required for ensuring the validity of the specifications, drawings and designs, and will be responsible for all its contents as like he prepare them himself". The Egyptian law make the contractor bears the whole responsibility of the soil investigation. But in article 651 of the civil code the Egyptian law make the consultant and the contractor jointly responsible for any defects due to any unforeseen site conditions.

These two articles may contradict with article 147 of Egyptian Civil Code where in which it is mentioned that the contract makes the law of the parties.Where, according to this article the owner and the contractor can agree on the responsibility of the soil investigation. But this is not allowed according to the article 80 of the Code number 98, 1989 and article 147 of Egyptian Civil Code. So, the contract clauses should agree with the Egyptian law.

Soil investigation is one of the most important procedures to reduce the risk of the unforeseen site conditions. Soil investigation stage for any construction project plays a vital role in reducing the risk of cost overrun and/or project duration extension due to unforeseen site conditions.

The expenses of soil investigations are minor comparing with the consequences that might happen ifsoil investigation is ignored. It is very important to add a clause or clauses in the contract to specify who is responsible for the unforeseen site conditions. The party who is responsible for these conditions will tend to make a proper soil investigation to reduce the risk of unforeseen site condition problems. It should be taken to the consideration that the responsible here is only responsible for the cost and time delay. While the consequences of unforeseen site conditions in case of partially or total failure is restricted in the law of each country.

The best way of avoiding the risk of the unforeseen site conditions is by making stages of soil investigation. The owner has to take a preliminary soil investigation to make it easier for the contractor to define the risk that he will face later due to the soil problems. The contractor in his turn should make an extra soil investigation to confirm or invert the owner soil investigation results. If the results of both soil investigation stages are identical, the contractor can take the decisions with high level of confidence. The extension of the confirmation soil investigation should be decided based on the preliminary soil investigation. If the two stages have large differences, a comprehensive soil investigation should take place to reach to the ideal representation for the soil under study.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. SUMMARY

Soil investigation is one of the first steps of any construction project. The objective of this thesis is to put a great emphasis on the importance of the soil investigation. The owner/contractor always tends to minimize the cost of construction by saving the cost of some of the project items. One of these items that the project owner/contractor may reduce or even eliminate its cost is the soil investigation. So, it is important to compare the cost of the soil investigation to the cost of the negative consequences that might happen due to this reduction. Another pointis who should bear the responsibility for making soil investigation. Is it the responsibility of the owner, the consultant, or the contractor? By searching in international laws,it appears that the responsibility is different from country to another, and the way of handling the responsibility is different. In this thesis, a number of international laws have been reviewed. On the other hand, in case of any dispute, the first reference to solve the disputebetween parties is the contract conditions. So, it is worthy to identify what right clauses(s)to be added to the construction contract to handle the soil investigation responsibility matter.

The purpose of asoil investigation is to collect a proper data concerning the geotechnical design. Based on these data the cost of the foundations could be estimated. The cost of the foundation depends on the type of the foundations. For example, the pile foundations system may cost much more than the cost of the isolated footings. As illustrated in Chapter two of this thesis, the soil investigation should be divided into two phases. First is a preliminary investigation, which involves collecting information about the regional geology and geological history. In this stage, a number of boreholes should be taken to give an indication about the soil nature. The second phase is a soil investigation designed to obtain data based on detailed measurements of soil properties. The quantity and depths of the soil investigation tests cannot be unified. It is always related to the type of the soil, soil layers, soil properties change, and building characteristics. Codes of design give a minimum number of tests (Boreholes) that must be taken for each type of project. This number gives an indication about if more tests must be taken or not. Most of the regular buildings owner and contractors takes this as the required soil investigation to be followed. The regular building owners and/or contractors consider only one stage of soil investigation to save cost andtime. As shown in the literature survey, there is another method to specify the soil investigation scope.This method is by specifying the soil investigation cost as a percentage of the construction cost or foundation cost. This method gives a minimum and maximum limit for the soil investigation cost. The approaching to the minimum or maximum limit of the soil investigation cost is depending mainly on the variation of the soil. Other factors should be taken also to consideration like project type, cost, foundation type, building purpose, building loads, and prior knowledge of site subsurface conditions

Inadequacy of soil investigations may lead to an increasein the projects' total cost, or may cause an increase of projects duration which leads, also, to an increase in project' total cost. The objective of this thesis is to study the effect of the inadequate soil on the total cost and duration construction. This came by studying cases that have a problem due to the inadequacy of the soil investigation. Another goal for this research is to show that the cost of extra soil investigation is usually minor comparing with the sequences that might happen due to the inadequacy of the soil investigation.

In order to meet the thesis objective, chapter 3 described the case studies. Six case studies with different conditions have been studied. In all of these cases the problem was because of inadequate or inappropriate soil investigation. Data collection has been conducted to provide evaluation of the effect of inadequate soil investigation. The collected data is the actual soil investigation, problems occurred, cause of problems and the correction action for these problems. After describing the project, the problem and its causes has been illustrated for each of these projects. The recommended procedures to rehabilitate these problems have been listed based on specialists' reports and/or the actual rehabilitations that have been taken in the site. In Chapter 3, also, the six case studies have been analyzed to evaluate the effect of the inadequate soil investigation. There was a slightly difference between the analysis of the cases because of the difference between the cases problem, causes, required rehabilitation and available data. In general, the main points that covered in this chapter are:

- Original soil investigation scope;
- original soil investigation cost;
- estimating the typicalsoil investigation cost;
- comparing the original soil investigation with the typical one;
- problem and corrective action;
- extra cost due to this problem;
- comparing the extra cost with the cost of the typicalsoil investigation; and,
- time extension due to the problem.

Chapter 4 has been specified to study the contractual and legal aspects of the soil investigation. The main objective of this chapter was to study the responsibility of the soil investigation. It has to be known who should identify the scope of the soil investigation, who is the responsible for taking it, and who is responsible for any consequences due to the inadequacy or inefficiency of it. Furthermore, the soil investigation responsibility should be considered when drafting the contracts. The responsibility of each of the owner, consultant and the contractor should be specified in the contracts.

To measure the opinion of the engineers who their work related to the soil investigation, a questionnaire survey has been conducted. The purpose of this questionnaire is to know how the issue of soil investigation can be effectively handled in the Egyptian law and the construction contracts respectively. After small introduction and some questions about the responder name, experience and field of work, the questionnaire consists of twelve questions. The responses of the questionnaire have been analyzed to reach to a conclusion of what is the major opinion about the questionnaire issues.

5.2. CONCLUSIONS

Inadequacy of the soil investigation may leads to insufficient knowledge of the ground conditions. Unforeseen geotechnical site conditions may appear and this may cause engineering and financial problems on various construction projects. Insufficient geotechnical investigation is one of the sources of costly, overdesigned foundation, project delays, disputes, claims, and project cost overruns.

The results of the analyses conducted in this research showed that the inadequacy of the soil investigation represents a major factor on the construction cost and duration. In fact, not only the inadequacy of the soil investigation is the only factor. Inappropriate or low quality soil investigation leads to the same results as the inadequacy of soil investigation. In one of the case studies, the cost of the soil investigation was more than the typical, but the poor quality of this soil investigation leads to many problems between the owner and the contractor. At the end, the owner terminates the contract with the contractor. In other case studies, inadequate soil investigation was the main problem. Inadequacy of thesoil investigation caused extra cost between 1.6 and 853 times the minimum typical soil investigation, and between 0.9 and 66 times the maximum typical soil investigation cost. In average, the extra cost due to the inadequacy of the soil investigation was 205 times the minimum typical soil investigation cost and 23.3times the maximum typical soil investigation cost.

The time delay due the inadequacy of the soil investigation has a very large variation. In one of the casesthe contract has been terminated before finishing the project. Inadequate soil investigation caused a delay in the case studies projects. This delay ranged between 6.6 % and 30.0% of the projects total duration.

The best procedure to avoid these problems is by making a proper soil investigation. The proper soil investigation comes in two phases. In the first phase, the owner should make a preliminary soil investigation before the bidding process. Before submitting his proposal, the contractor should take into consideration, based on the preliminary soil investigation, whatever if more investigation is required or not. If more soil investigation is required, the scope of the extra soil investigation should be identified.

The expenses of the soil investigation are minor comparing with the consequences that might happen if the soil investigation was ignored. It is very important to add a clause or clauses in the contract to specify who is responsible for the unforeseen site conditions. The party who is responsible for these conditions will tend to make a proper soil investigation to reduce the risk of unforeseen site condition problems. It should be taken to the consideration that the responsibility here is only for the cost and time delays. While the consequences of unforeseen site conditions in case of partially or total failure is restricted in the law of each country. According to the Egyptian law, the responsibility of any destruction due to inadequate soil investigation is held by the consultant and the contractor. So, they should convince the owner to make a proper soil investigation if the owner underestimated its usefulness.

5.3. RECOMMENDATIONS

Soil investigation phase of any geotechnical design plays a vital role, where inadequate data concerning the subsurface conditions may contribute significant problems. The first recommendation is to make a proper soil investigation. Based on the study carried on this thesis, the most proper soil investigation procedures are to make a preliminary soil investigation by the owner, then a confirmation soil investigation by the contractor.

The second recommendation is to identify the minimum soil investigation as a percentage of the construction cost. The Egyptian code of practice defined the minimum number of boreholes for each type of construction. This minimum number does not take into consideration the soil type, building loads, number of floors, foundationstype, project type, foundationscost, building purpose, and prior knowledge of soil subsurface conditions. Due to these multi conditions, it is difficult to specify the number of the required soil investigation. So, the best way is to identify it as a percentage of the construction cost. This should be besides identifying the minimum number of boreholes for each type of construction.

The third recommendation is related to the Egyptian law. The whole responsibility of the soil investigation in the Egyptian law is on the contractor. The Egyptian law/code should obligate the owner to make a preliminary soil investigation. By making a preliminary soil investigation the type and depth of foundations, as well as foundation construction procedure could be specified. Based on this soil investigation the contractor can take a decision if further soil investigation required before submitting his proposal, and how further the project soil investigation should be extended.

The fourth recommendation is to use the international laws to improve the Egyptian law in this point. One of the following two scenarios might be considered.

- In the first scenario, like the Italian law, the contractor right of asking for extra cost and/or duration due to any unforeseen site conditions might be attach to the effect that these conditions make. The project cost and/or time must exceed certain limit of the contract price and/or duration before the contractor has a right to ask for extra cost and/or duration.
- In the other scenario, like FIDIC and New Zealand law. This scenario is giving the contractor the right of asking for variation in case of finding unforeseen site conditions. By this variation, the contractor might havea right of asking for extra cost and/or duration if he faced unforeseen site conditions. It should be mentioned that this point is included in the ministerial decrees guiding contracts. The law is clear about the responsibility of the contracts to check the nature of work himself even if the owner made any tests.

Because the Egyptian law is solid, the last recommendation is for the contractors. A pretender soil investigation can be performed by the group of the contractors who are interested in submitting proposals. They can share the soil investigation cost. The winner contractor may or may not return the soil investigation expenses to other contractors. This should be decided based on an agreement between these contractors. This method is more efficient in large projects.

5.4. RECOMMENDATIONS FOR FURTHER RESEARCHES

The adequacy of the soil investigation is difficult to measure. A lot of studies are required to define it in both ways technically and financially. The current estimation for the soil investigation scope in the codes is far from the estimated soil investigation cost as a percentage from the construction cost. One of the most interestingsubjects to be studied is what is the definition (Financially and technically) of the adequate soil investigation.

Another issue to be searched is the relation between soil investigation responsibility and contracts type. Who should take the responsibility of the soil investigation in case of lump sum, unit price and cost plus contracts. It might be better to handle the soil investigation by one of the contract parties in certain type of contracts, and other partyin another contract type.

The study of the risk of the soil investigation may be necessary. By studying the risk of soil investigation, a number could be representing the risk. By quantifying this risk, any required soil investigation, or the probable later problems due to any unforeseen soil conditions may be covered.

It might be beneficial to study the relation between the risk of the unforeseen soil conditions and the foundations type. Since each type of foundations interact in different manner with the soil beneath it, so the effect of soil variation may differ from type of foundations to another.

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APPENDICES

APPENDIX 1

QUESTIONNAIRE SURVEY RESPONSES SAMPLES

The Questionnaire Respondents

No.	Name	Occupation	Organization
1	Dr. Mohammed ElkhairySalama	Assistant Professor	Port Said University
2	Dr. Mohammed MosaadElgendy	Associate Professor	Port Said University
3	Dr. WaleedAbdelmoghnyOgila	Assistant Professor	Ain Shams University
4	Eng. Waleed Ahmed Mohammed	Goetechnical Eng.	Banha University
5	Eng. Mohamed Ahmed Nabaway	Civil Engineer	AAW Consulting Co.
6	Eng. Ahmed Abdullah Elhashmy	Goetechnical Eng.	Banha University
7	Eng. HussainElsawah	Civil Engineer	Orascom Construction
8	Eng. Mohammed MohammedAlhazmi	Site Engineer	Eco
9	Eng. Mohammed Ammar	Site Engineer	
10	Eng. BasheerAlhazmi	Civil Engineer	Elsaid Construction
11	Eng. Mostafa Mohammed Abozaid	Site Engineer	Arab Contractors
12	Eng. HanyMostafaKamel	Site Engineer	Arab Contractors
13	Eng. Fares Kamal Ibrahim	Site Engineer	Alelian Contractors
14	Eng. Ahmed IsmaealShazly	Site Engineer	TalaatMostafa
15	Eng. Noha Ahmed Rabie	Geotechnical Engineer	Hamza Associates
16	Eng. Rabab Ahmed	Civil Engineer	Orascom Construction
17	Eng. Mohammed Soilem	Civil Engineer	Orascom Construction
18	Eng. Ehab Mohsen	Civil Engineer	Orascom Construction
19	Eng. Aya Ahmed Kamel	Geotechnical Engineer	Hamza Associates
20	Eng. FadyRoshdyZehry	Geotechnical Engineer	Hamza Associates
21	Eng. Walid Ahmed Khalif	Senior Civil Engineer	Armed Forces Engineering Authority
22	Eng. Omar Nshaat Nor	Site Engineer	
23	Eng. Khaled Mohammed Dawood	Civil Engineer	Hamza Associates
24	Eng. Hosaam Mohammed Ali	Civil Engineer	Irrigation Minestry
25	Eng. Mohammed Saeed Ibrahim	Site Engineer	TalaatMostafa
26	Eng. Islam Elsayed	Site Engineer	Eco
27	Eng. Abo Bakr Mohammed	Civil Engineer	I.C.
28	Eng. Mohammed MostafaDarwish	Site Engineer	Hamza Associates
29	Eng. Mohammed RoshdyBadawy	Planning Engineer	Mahmodia Consultants
30	Eng. MostafaMohmoudOmira	Civil Engineer	Arab Contractors
31	Eng. Magdy Ali Elbaily	Consulting Engineer	Hamza Associates

بسم الله الرحمن الرحيم

<u>إستبيـــــــان</u>

السيد:- مهندس / وليد أحمد خليف

المهنة :- رئيس فرع مشروعات الخدمة الوطنية الشركة :- الهيئة الهندسية للقوات المسلحة

أود إحاطتكم علماً بأني طالب في مرحلة الماجستير في الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري. وانا في مرحلة إعداد الرسالة البحثية لنيل درجة الماجستير في مجال إدارة المشاريع الهندسية والتي هي بعنوان:-

"Effect of Inadequate Site Investigation on the Cost and Time of Construction Projects"

"تأثير عدم كفاية ابحاث التربة على تكلفة وزمن مشاريع التشييد"

وبصفتكم أحد العاملين في هذا المجال في مصر فأن مشاركتكم بالإجابة على هذا الإستبيان بالمعلومات المناسبة يعتبر جزء مهم يُثري الموضوع ويجعله ذو فائده علمية.

ونحن شاكرين تعاونكم بالإجابة على هذا الإستبيان والذي لن يأخذ من وقتكم الثمين اكثر من 15 دقيقة.

ونؤكد لكم أن الغرض الوحيد لهذا الاستبيان هو للبحث العلمي وان المعلومات سوف يتم تحليلها ودراستها كوحده واحده.

المشرفون على الرسالة

أ.د. محمد إمـــام عبدالرازق

أستاذ إدارة المشاريع في قسم التشييد والبناء بكلية الهندسة والتكنولوجيا بالأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

د. حسام الدين حسني محمد

قسم هندسة التشييد في كلية الهندسة بجامعة الزقازيق

الباحث

م. علي حفظ الله البطل

معلومات عامة

الرجاء كتابة أو إختيار الإجابة المناسبة للأسئلة التالية:-

س (1):- متى كانت بداية عمل شركتكم في مجال الإنشاءات؟

ج (1):- (أ) اقل من 5 سنوات ( ) (أ) من 5 الي 10 سنوات ( )

(ج) من 10 الي 15 سنة ( ) (د) أكثر من 15 سنة (√)

س (2):- ما هو تصنيف شركتكم طبقاً للإتحاد المصري لمقاولي التشييد والبناء او ما يقابله؟

ج (2) :- (أ) درجة أولى (√) (ب) درجة ثانية ( )

(ج) درجة ثالثة ( ) (د) درجة رابعة ( )

(هـ) درجة خامسة ( ) (و) درجة سادسة ( )

س (3):- ما هي نوعية المشاريع التي سوف تعتمد عليها للإجابة على الأسئلة؟

ج (3) :- (أ) مشاريع عامة (√) (ب) مشاريع خاصة ( )

مقدمـــة

الظروف الغير ظاهرة قد يكون لها تأثير على تكلفة و وقت المشاريع حيث أنها قد تمنع الأطراف من أداء التزاماتها التعاقدية أحياناً أو تجعل أداء هذة الإلتزامات أصعب أو أعلى تكلفة أحياناً أخرى.

لم تنص معظم القوانين والأكواد صراحة على من تقع مسئولية عمل أبحاث التربة ولكن حددت من هو المسئول عن اي ظروف أو عوامل غير متوقعه او مخفية. وبالتالي يكون من الطبيعي أن المسئول عن أي احداث او ظروف غير متوقعه هو المسئول عن التحري عن وجود هذة الظروف. ويلخص الجدول التالي نصوص بعض القوانين لبعض الدول التي حددت من هو المسئول عن الظروف غير المتوقعة.

الفيديك	**البند رقم 4-10 "بيانات الموقع "** على رب العمل أن يضع تحت تصرف المقاول لمعلوماته قبل تاريخ الاساس ، كل البيانات التي يمتلكها والمتعلقة بظروف تحت سطح الأرض وهيدرولوجية الموقع، بما فيها النواحي البيئية وعلى رب العمل أيضاً أن يوفر للمقاول كل تلك البيانات التي يحصل عليها رب العمل بعد تاريخ الأساس. والمقاول مسئول عن تفسير كل هذه البيانـــات. **البند رقم 4-12 "الظروف المادية غير المتوقعة** إذا واجه المقاول ظروف مادية معاكسة التي تعتبر من وجهة نظر المقاول غير متوقعة ، على المقاول أن يخطر المهندس في أسرع وقت ممكن. هذا الإخطار يجب أن يصف الظروف المادية ، حتى أن يقوم المهندس بفحص هذه الظروف، ويوضح الأسباب التي جعلت المقاول يعتبر هذه الظروف غير متوقعة ، وعلى المقاول أن يستمر في الأعمال مستخدماً القياسات اللائقة والمناسبة لهذه الظروف المادية ، ويجب أن يمتثل لاي تعليمات يعطيها المهندس وإذا شكل أي من هذه التعليمات تغيرات فيجب إعمال البند 13 (التغيرات والتعديلات).
القانون المصري	**مادة 80 في القانون رقم 98 لسنة 1989** يلتزم المقاول بأن يتحرى بنفسة طبيعة الأعمال وعمل كل ما يلزم لذلك من إختبارات وغيرها للتأكد من صلاحية المواصفات والرسومات والتصاميم المعتمدة وعلية إخطار الجهة الإدارية في الوقت المناسب بملاحظته عليها ويكون مسئولاً تبعاً لذلك عن صحة وسلامة جميع ما ورد بها كما لو كانت مقدمة منه. **مادة 651 في القانون المدني المصري** يضمن المهندس المعماري والمقاول متضامنين ما يحدث خلال عشر سنوات من تهدم كلى أو جزئي فيما شيدوه من مبان أو أقاموه من منشآت ثابتة أخرى وذلك ولو كان التهدم ناشئاً عن عيب فى الأرض ذاتها، أو كان رب العمل قد أجاز إقامة المنشآت المعيبة ، ما لم يكن المتعاقدان فى هذه الحالة قد أرادا أن تبقى هذه المنشآت مدة أقل من عشر سنوات. - ويشمل الضمان المنصوص عليه فى الفقرة السابقة ما يوجد فى المباني والمنشآت من عيوب يترتب عليها تهديد متانة البناء وسلامته - وتبدأ مدة السنوات العشر من وقت تسلم العمل ولا تسرى هذه المادة على ما قد يكون للمقاول من حق الرجوع على المقاولين من الباطن.
القانون الفرنسي	المسئولية عن الظروف غير الظاهرة الطبيعية المتعلقة بالأرض يجب ان يتحملها المقاول.
القانون الألماني	المالك يتحمل مخاطر الظروف غير الظاهرة في التربة التحتية.
القانون الأيطالي	في حالة الأحداث غير الظاهرة، يجب ا، تزيد تكلفة المشروع بالنسبة للوقت والمواد عن 10% من قيمة العقد قبل أن يحق للمقاول المطالية بتعديل العقد بما في ذلك الوقت والسعر.
القانون النيوزلندي	يضمن المالك للمقاول قبل تقديم العطاء توفير كل المعلومات عن طبيعة الأرض المتعلقة بالأعمال التي يشتمل عليها العقد. ولكن لا يظمن المالك كفاية أو دقة هذة المعلومات ويكون المقاول مسئولاً عن تفسير كل هذه المعلومات لأغراض الأعمال المتعاقد عليها.
القانون الماليزي	على المقاول فحص وإختبار الموقع ومحيطه حتى يكون راضٍ بنفسه قبل تقديم العطاء.

وبناءً علية فإن هناك كثير من الأسئلة تحتاج الي إجابة عن أبحاث التربة وخاصة القانون المصري والكود المصري للأساسات، لذا نرجو منكم الإجابة على الأسئلة التالية:-

1. كيف ترى خطورة الظروف غير الظاهرة في الموقع؟

(أ) عالية جداً (√) (ب) عالية ( ) (ب) متوسطة ( )

(أ) منخفضة ( ) (ب) منخفضة جداً ( )

2. هل تجد الكود المصري عملياً من ناحية تعاملة مع أبحاث التربة من الناحية التقنية؟

(أ) نعم (√) (ب) لا ( )

3. هل يتم عمل أبحاث تربة بشكل مناسب في المشاريع التي تعملون بها؟

(أ) دائماً (√) (ب) غالباً ( )

(أ) أحياناً ( ) (ب) أبداً ( )

4. ما هو تكرار تطابق أبحاث التربة مع ما تجدونة في الموقع؟

(أ) دائماً ( ) (ب) غالباً (√)

(أ) أحياناً ( ) (ب) أبداً ( )

5. ما هو تكرار مواجهتكم لعيوب غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً (√) (ب) أبداً ( )

6. ما هو تكرار زيادة تكاليف المشاريع عن الميزانية المخطط لها نتيجة لمواجهة عيوب غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً (√) (ب) أبداً ( )

7. ما هو تكرار إمتداد زمن المشاريع عن الزمن المخطط لها نتيجة لمواجهة عيوب غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً (√) (ب) أبداً ( )

8. من واقع خبرتكم من هو المسئول عن الظروف غير الظاهرة التي تطرأ خلال إنشاء المشروع؟

(أ) المالك ( ) (ب) المقاول ( )

(أ) المسئولية مشتركة ما بين المالك والمقاول بشكل ما (√)

9. ما هو سبب اختيارك لإجابة السئوال رقم (8)؟

لانة يجب ان تكون المسئولية مشتركة بينهم حتى يقوم كل طرف بتحمل مسئولياتة لانجاح العمل و انجازة على اكمل وجة

10. أذا كانت اجابتك للسئوال رقم (8) هي أن المسئولية مشتركة ما بين المالك والمقاول بشكل ما فما هي الطريقة المقترحة لمشاركة المسئولية بينهما ؟

يجب على المالك قبل الشروع فى تنفيذ مشروعة او اسنادة الى المقاول ان يلزم الاستشارى بعمل أبحاث للتربة باحدى الجامعات او المراكز المعتمدة , و على المقاول قبل البدء فى التنفيذ ان يتأكد من نوعية التربة و مدى مطابقتها لتقرير الجسات و ذلك بعمل جسة تأكيدية قبل التنفيذ .

11. ما هي إقتراحاتكم لتعديل القانون المصري لتحسينة في مجال أبحاث التربة لتفادي أخطار الظروف غير الظاهرة ؟

يجب ان يلزم القانون المصرى المقاول بعمل جسة تاكيدية قبل بدء العمل .

12. ما هي الشروط المقترح إضافتها الي العقود لتغطية مسئولية ظهور الظروف غير الظاهرة ؟

1- إلزام المالك بتقديم تقرير للتربة حديث الى المقاول .
2- إلزام المقاول بعمل جسة تأكيدية قبل البدء فى تنفيذ المشروع .
3- إلزام الاستشارى باعتماد التقرير الجديد لنوعية التربة الذى قام المقاول بتقديمة .
4- إلزام المالك بتحمل التكلفة المالية فى حالة وجود اختلاف بين التقريرين .

بسم الله الرحمن الرحيم

Questionnaire

Dear Mr.:- Mohamed Ahmed Nabawy

Occupation:- Civil Engineer Company:- AAW Consultancy Company

I am a graduate student at Arab Academy Science and Technology and Maritime Transport. I am now preparing a master thesis in the construction engineering and management program. The title of the thesis is:-

"Effect of Inadequate Site Investigation on the Cost and Time of Construction Projects"

As you are one of the organizations working in this field in Egypt, your participation in filling this questionnaire with the required data is an important element in this research and offering valuable result for all.

We appreciate your cooperation in answering this questionnaire, which may take about 15 minutes of your valuable time.

All data will be analyzed as whole, and will be used for this purpose of scientific research only.

Advising Professors

Prof. Mohamed Emam Abd EL- Razek

Prof. of Construction Management, construction &build Eng. Depart. College of engineering and technology, Arab academy for Science, Technology Maritime Transport, Cairo, EGYPT

Dr. Hossam El- deen Hosny Mohamed

Construction Engineering Dept., ZAGAZIG University, EGYPT

Researcher

Eng. Ali Hefdh-Allah Albatal

General Information

You are kindly requested to write or choose the appropriate answer for following question:-

Q1:- How many years has your firm been in the Egyptian construction market?

S1:- (a) Less than 5 years ( ) (b) 5 to 10 years ( )

(c) 10 to 15 years ( ) (d) Over 15 years (√)

Q2:- What is the classification grade of your company according to the Egyptian Federation for construction?

S2:- (a) First (√) (b) Second ( )

(c) Third ( ) (d) Fourth ( )

(e) Fifth ( ) (f) Sixth ( )

Q3:- Select the type of projects which your answer in this questionnaire will depend on?

S3:- (a) Public projects (√) (b) Private Projects (√)

Introduction

Unforeseen conditions may have an impact on time and cost. Sometimes they may prevent the parties form performing their contractual obligations, and other times they only make it harder or more costly to perform the contract. The laws and codes did not specify who is responsible for taking the site investigation, but most of laws have been identified who is the responsible for any unforeseen site conditions. It could be concluded that by default the responsible for unforeseen site condition is the one who is also responsible for investigate these conditions. The following table summarized the responsibility bearing for the unforeseen site conditions for some countries.

FIDIC	The Employer shall have made available to the Contractor for his information, prior to the Base Date, all relevant data in the Employer's possession on sub-surface and hydrological conditions at the Site, including environmental aspects. The Contractor shall be responsible for interpreting all such data. If the Contractor encounters adverse physical conditions which he considers to have been unforeseeable, the Contractor shall give notice to the Engineer as soon as practicable. This notice shall describe the physical conditions, so that they can be inspected by the Engineer, and shall set out the reasons why the Contractor considers them to be unforeseeable. The Contractor shall continue executing the works, using such proper and reasonable measurers as are appropriate for the physical condition, and shall comply with any instructions which the Engineer may give, if an instruction constitutes a Variation, Clause 13 (Variations and Adjustments) shall apply.
Egyptian Law	The contractor is responsible for checking the nature of the work including any tests required for ensuring the validity of the specifications, drawings and designs, and will be responsible for all its contents as like he prepare them himself. The engineer and contractor are jointly and severally responsible for a period of ten years for the total or partial demolition of constructions or other permanent works erected by them, even if such destruction is due to a defect in the ground itself, and even if the master authorized the erection of the defective construction.
French Law	The responsibility for unforeseeable physical conditions related to the ground shall be taken by the contractor.
German Law	The Employer bears the risk of unforeseen subsoil conditions.
Italian Law	The case of unforeseen events, the project cost for time and materials must exceed 10% of the original contract price before the contractor has a right to ask for revisions to the contract including time and price.
New Zealand Law	The Principal warrants that it has made available to the contractor before the submission of the contractor's tender all information of which it is aware on the nature of the physical conditions relevant to the contract works. The Principal makes no warranty as to the sufficiency or accuracy of such information. The contractor shall be responsible for the interpretation of all such information for the purposes of the contract works.
Malaysian law	The contractor shall be deemed to have inspected and examined the site and its surroundings and to have satisfied himself before submitting his tender.

Accordingly, many questions needed to be answered about site investigation especially in the Egyptian law. Kindly answer the following question:

1. How do you think the risk of unforeseen site investigation?

   (a) V. High ( ) (b) High (√) (c) Medium( )

   (d) Low ( ) (e) V. Low ( )

2. Is the Egyptian code of practice deals properly with site investigation from the technical point of view?

   (a) Yes (√) (b) No ( )

3. Did the site investigation made properly in the projects you have worked on?

   (a) Always ( ) (b) Often ( )

   (c) Sometimes (√) (e) Never ( )

4. How many times have you found the soil interpretation identical to the site investigation report?

   (a) Always ( ) (b) Often (√)

   (c) Sometimes ( ) (e) Never ( )

5. How often did you face unforeseen site conditions?

   (a) Always ( ) (b) Often ( )

   (c) Sometimes (√) (e) Never ( )

6. What is the frequency of occurrence for increasing the cost of project more than it planned, result for facing unforeseen site conditions during construct the project?

   (a) Always (√) (b) Often ( )

   (c) Sometimes ( ) (e) Never ( )

7. What is the frequency of occurrence for increasing the duration of project more than it planned, result for facing unforeseen site conditions during construct the projects?

   (a) Always ( ) (b) Often ( )

   (c) Sometimes (√) (e) Never ( )

8. From your experience who should take the responsibility of the unforeseen site conditions?

(a) The owner ( ) (b) The contractor (√)

(c) Sharing the responsibility somehow between them ( )

9. What was the reason for your answer in the question (8)?

For example in case of discovery of rock excavation or high ground water table or a site surrounding by unexpected gas underground. All of these conditions if not realized at the tender stage before evaluating the BOQ and placing the site Program Schedule would lead to an increase in cost and may effect time.

10. If your answer in question (8) was sharing the unforeseen conditions responsibility between the owner and contractor, what is the sharing method that you suppose it would be appropriate?

It is Contractors responsibility.

11. What are your suggestions to modifying the Egyptian law to improve it in the field of site investigation?

By certain means develop the contractors vision by importance of site investigation prior start of work.

12. In your opinion what are the clauses to be added to the contracts to cover the site investigation responsibility?

Contractor is to be responsible for any obstacles on site prior start of construction works.

إستـبـيـــــــان

السيد: أحمد أسماعيل شاذلى

المهنة: مهندس تنفيذ الشركة:- طلعت مصطفى

أود إحاطتكم علماً بأني طالب في مرحلة الماجستير في الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري. وانا في مرحلة إعداد الرسالة البحثية لنيل درجة الماجستير في مجال إدارة المشاريع الهندسية والتي هي بعنوان:-

"Effect of Inadequate Site Investigation on the Cost and Time of Construction Projects"

"تأثير عدم كفاية ابحاث التربة على تكلفة وزمن مشاريع التشييد"

وبصفتكم أحد العاملين في هذا المجال في مصر فأن مشاركتكم بالإجابة على هذا الإستبيان بالمعلومات المناسبة يعتبر جزء مهم يُثري الموضوع ويجعله ذو فائده علمية.

ونحن شاكرين تعاونكم بالإجابة على هذا الإستبيان والذي لن يأخذ من وقتكم الثمين اكثر من 15 دقيقة.

ونؤكد لكم أن الغرض الوحيد لهذا الاستبيان هو للبحث العلمي وان المعلومات سوف يتم تحليلها ودراستها كوحده واحده.

المشرفون على الرسالة

أ.د. محمد إمــــام عبدالرازق

أستاذ إدارة المشاريع في قسم التشييد والبناء بكلية الهندسة والتكنولوجيا بالأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

د. حسام الدين حسني محمد

قسم هندسة التشييد في كلية الهندسة بجامعة الزقازيق

الباحث

م. علي حفظ الله البطل

معلومات عامة

الرجاء كتابة أو إختيار الإجابة المناسبة للأسئلة التالية:-

س (1):- متى كانت بداية عمل شركتكم في مجال الإنشاءات؟

ج (1):- (أ) اقل من 5 سنوات ( ) (أ) من 5 الي 10 سنوات ( )

(ج) من 10 الي 15 سنة ( ) (د) أكثر من 15 سنة (√)

س (2):- ما هو تصنيف شركتكم طبقاً للإتحاد المصري لمقاولي التشييد والبناء او ما يقابله؟

ج (2) :- (أ) درجة أولى (√) (ب) درجة ثانية ( )

(ج) درجة ثالثة ( ) (د) درجة رابعة ( )

(هـ) درجة خامسة ( ) (و) درجة سادسة ( )

س (3):- ما هي نوعية المشاريع التي سوف تعتمد عليها للإجابة على الأسئلة؟

ج (3) :- (أ) مشاريع عامة ( ) (ب) مشاريع خاصة (√)

مقدمـــة

الظروف الغير ظاهرة قد يكون لها تأثير على تكلفة و وقت المشاريع حيث أنها قد تمنع الأطراف من أداء التزاماتها التعاقدية أحياناً أو تجعل أداء هذة الإلتزامات أصعب أو أعلى تكلفة أحياناً أخرى.

لم تنص معظم القوانين والأكواد صراحة على من تقع مسئولية عمل أبحاث التربة ولكن حددت من هو المسئول عن اي ظروف أو عوامل غير متوقعه او مخفية. وبالتالي يكون من الطبيعي أن المسئول عن أي احداث او ظروف غير متوقعه هو

المسئول عن التحري عن وجود هذة الظروف. ويلخص الجدول التالي نصوص بعض القوانين لبعض الدول التي حددت من هو المسئول عن الظروف غير المتوقعة.

الفيديك	**البند رقم 4-10 "بيانات الموقع "** على رب العمل أن يضع تحت تصرف المقاول لمعلوماته قبل تاريخ الاساس ، كل البيانات التي يمتلكها والمتعلقة بظروف تحت سطح الأرض وهيدرولوجية الموقع، بما فيها النواحي البيئية وعلى رب العمل أيضاً أن يوفر للمقاول كل تلك البيانات التي يحصل عليها رب العمل بعد تاريخ الأساس. والمقاول مسئول عن تفسير كل هذه البيانـــات. **البند رقم 4-12 "الظروف المادية غير المتوقعة** إذا واجه المقاول ظروف مادية معاكسة التي تعتبر من وجهة نظر المقاول غير متوقعة ، على المقاول أن يخطر المهندس في أسرع وقت ممكن. هذا الإخطار يجب أن يصف الظروف المادية ، حتى أن يقوم المهندس بفحص هذه الظروف، ويوضح الأسباب التي جعلت المقاول يعتبر هذه الظروف غير متوقعة ، وعلى المقاول أن يستمر في الأعمال مستخدماً القياسات اللائقة والمناسبة لهذه الظروف المادية ، ويجب أن يمتثل لاي تعليمات يعطيها المهندس وإذا شكل أي من هذه التعليمات تغيرات فيجب إعمال البند 13 (التغيرات والتعديلات).
القانون المصري	**مادة 80 في القانون رقم 98 لسنة 1989** يلتزم المقاول بأن يتحرى بنفسة طبيعة الأعمال وعمل كل ما يلزم لذلك من إختبارات وغيرها للتأكد من صلاحية المواصفات والرسومات والتصاميم المعتمدة وعلية إخطار الجهة الإدارية في الوقت المناسب بملاحظته عليها ويكون مسئولاً تبعاً لذلك عن صحة وسلامة جميع ما ورد بها كما لو كانت مقدمة منه. **مادة 651 في القانون المدني المصري** يضمن المهندس المعماري والمقاول متضامنين ما يحدث خلال عشر سنوات من تهدم كلى أو جزئي فيما شيدوه من مبان أو أقاموه من منشآت ثابتة أخرى وذلك ولو كان التهدم ناشئاً عن عيب فى الأرض ذاتها، أو كان رب العمل قد أجاز إقامة المنشآت المعيبة ، ما لم يكن المتعاقدان فى هذه الحالة قد أرادا أن تبقى هذه المنشآت مدة أقل من عشر سنوات. - ويشمل الضمان المنصوص عليه فى الفقرة السابقة ما يوجد فى المباني والمنشآت من عيوب يترتب عليها تهديد متانة البناء وسلامته - وتبدأ مدة السنوات العشر من وقت تسلم العمل ولا تسرى هذه المادة على ما قد يكون للمقاول من حق الرجوع على المقاولين من الباطن.
القانون الفرنسي	المسئولية عن الظروف غير الظاهرة الطبيعية المتعلقة بالأرض يجب ان يتحملها المقاول.
القانون الألماني	المالك يتحمل مخاطر الظروف غير الظاهرة في التربة التحتية.
القانون الأيطالي	في حالة الأحداث غير الظاهرة، يجب ا، تزيد تكلفة المشروع بالنسبة للوقت والمواد عن 10% من قيمة العقد قبل أن يحق للمقاول المطالبة بتعديل العقد بما في ذلك الوقت والسعر.

القانون النيوزلندي	يضمن المالك للمقاول قبل تقديم العطاء توفير كل المعلومات عن طبيعة الأرض المتعلقة بالأعمال التي يشتمل عليها العقد. ولكن لا يظمن المالك كفاية أو دقة هذة المعلومات ويكون المقاول مسئولاً عن تفسير كل هذه المعلومات لأغراض الأعمال المتعاقد عليها.
القانون الماليزي	على المقاول فحص وإختبار الموقع ومحيطه حتى يكون راضٍ بنفسه قبل تقديم العطاء.

وبناءً علية فإن هناك كثير من الأسئلة تحتاج الي إجابة عن أبحاث التربة وخاصة القانون المصري والكود المصري للأساسات، لذا نرجو منكم الإجابة على الأسئلة التالية:-

1. كيف ترى خطورة ظروف التربة غير الظاهرة في الموقع؟

(أ) عالية جداً ( ) (ب) عالية (√) (ب) متوسطة ( )

(أ) منخفضة ( ) (ب) منخفضة جداً ( )

2. هل تجد الكود المصري عملياً من ناحية تعاملة مع أبحاث التربة من الناحية التقنية؟

(أ) نعم ( ) (ب) لا (√)

3. هل يتم عمل أبحاث تربة بشكل مناسب في المشاريع التي تعملون بها؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً (√) (ب) أبداً ( )

4. ما هو تكرار تطابق أبحاث التربة مع ما تجدونة في الموقع؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً ( ) (ب) أبداً ( )

5. ما هو تكرار مواجهتكم لعيوب التربة غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً ( ) (ب) أبداً (√)

6. ما هو تكرار زيادة تكاليف المشاريع عن الميزانية المخطط لها نتيجة لمواجهة عيوب التربة غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً ( ) (ب) أبداً (√)

7. ما هو تكرار إمتداد زمن المشاريع عن الزمن المخطط لها نتيجة لمواجهة عيوب التربة غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً ( ) (ب) أبداً (√)

8. من واقع خبرتكم من هو المسئول عن ظروف التربة غير الظاهرة التي تطرأ خلال إنشاء المشروع؟

(أ) المالك ( ) (ب) المقاول (√)

(أ) المسئولية مشتركة ما بين المالك والمقاول بشكل ما (√)

9. ما هو سبب اختيارك لإجابة السئوال رقم (8)؟

بالنسبه للمقاول أن يتأكد من أن التربه صالحه للمشروع و ان يبلغ المالك فى حاله وجود عوائق ذلك لأنه يمتلك أمكانيات تجعله قادرا على التأكد من صلايه التربه. أما بالنسبه للمالك فأذا توافرت الامكانيه لديه فيجب عليه أن يخبر المقاول بما لديه من معلومات عن التربه و فى أغلب الأحيان المالك يمكن أن يحصل بكل سهوله على تقرير التربه.

10. أذا كانت اجابتك للسئوال رقم (8) هي أن المسئولية مشتركة ما بين المالك والمقاول بشكل ما فما هي الطريقة المقترحة لمشاركة المسئولية بينهما ؟

النسبه تكون متساويه.

11. ما هي إقتراحاتكم لتعديل القانون المصري لتحسينة في مجال أبحاث التربة لتفادي أخطار ظروف التربة غير الظاهرة ؟

أقترح ان يضيف ماده تحبر المالك على أن يقدم تقرير للتربه للمقاول الذى يرسى عليه العطاء.

12. ما هي الشروط المقترح إضافتها الي العقود لتغطية مسئولية ظهور ظروف التربة غير الظاهرة ؟

أن تضيف شرطين :

1- أن تجبر المالك على تقديم تقرير للتربه و أن كان بسيطا للمقاول خلال 14 يوم من تاريخ أمضاء العقد.

2- أن تضيف بند تحدد فيه نسبه تحمل المالك و المقاول من الخسائر الناتجه.

إستبيـــــــان

السيد:- نهى احمد ربيع

المهنة:- مهندسة الشركة/الجامعة:-.............مكتب حمزه ومشاركوه........

أود إحاطتكم علماً بأني طالب في مرحلة الماجستير في الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري. وانا في مرحلة إعداد الرسالة البحثية لنيل درجة الماجستير في مجال إدارة المشاريع الهندسية والتي هي بعنوان:-

"Effect of Inadequate Site Investigation on the Cost and Time of Construction Projects"

"تأثير عدم كفاية ابحاث التربة على تكلفة وزمن مشاريع التشييد"

وبصفتكم أحد العاملين في هذا المجال في مصر فأن مشاركتكم بالإجابة على هذا الإستبيان بالمعلومات المناسبة يعتبر جزء مهم يُثري الموضوع ويجعله ذو فائده علمية.

ونحن شاكرين تعاونكم بالإجابة على هذا الإستبيان والذي لن يأخذ من وقتكم الثمين اكثر من 15 دقيقة.

ونؤكد لكم أن الغرض الوحيد لهذا الاستبيان هو للبحث العلمي وان المعلومات سوف يتم تحليلها ودراستها كوحده واحده.

المشرفون على الرسالة

أ.د. محمد إمـــام عبدالرازق

أستاذ إدارة المشاريع في قسم التشييد والبناء بكلية الهندسة والتكنولوجيا بالأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

د. حسام الدين حسني محمد

قسم هندسة التشييد في كلية الهندسة بجامعة الزقازيق

الباحث

م. علي حفظ الله البطل

معلومات عامة

الرجاء كتابة أو إختيار الإجابة المناسبة للأسئلة التالية:-

س (1):- متى كانت بداية عمل شركتكم/مكتبكم في مجال الإنشاءات؟

ج (1):- (أ) اقل من 5 سنوات ( ) (أ) من 5 الي 10 سنوات ( )

(ج) من 10 الي 15 سنة ( ) (د) أكثر من 15 سنة (*)

س (1):- ما هي عدد سنوات الخبرة لديك في مجال الإنشاءات؟

ج (1):- (أ) اقل من 5 سنوات ( ) (أ) من 5 الي 10 سنوات (*)

(ج) من 10 الي 15 سنة ( ) (د) أكثر من 15 سنة ( )

س (3):- ما هي نوعية المشاريع التي سوف تعتمد عليها للإجابة على الأسئلة؟

ج (3) :- (أ) مشاريع عامة (*) (ب) مشاريع خاصة (*)

مقدمـــة

الظروف الغير ظاهرة قد يكون لها تأثير على تكلفة و وقت المشاريع حيث أنها قد تمنع الأطراف من أداء التزاماتها التعاقدية أحياناً أو تجعل أداء هذة الإلتزامات أصعب أو أعلى تكلفة أحياناً أخرى.

لم تنص معظم القوانين والأكواد صراحة على من تقع مسئولية عمل أبحاث التربة ولكن حددت من هو المسئول عن اي ظروف أو عوامل غير متوقعه او مخفية. وبالتالي يكون من الطبيعي أن المسئول عن أي احداث او ظروف غير متوقعه هو المسئول عن التحري عن وجود هذة الظروف. ويلخص الجدول التالي نصوص بعض القوانين لبعض الدول التي حددت من هو المسئول عن الظروف غير المتوقعة.

الفيديك	**البند رقم 4-10 "بيانات الموقع "** على رب العمل أن يضع تحت تصرف المقاول لمعلوماته قبل تاريخ الاساس ، كل البيانات التي يمتلكها والمتعلقة بظروف تحت سطح الأرض وهيدرولوجية الموقع، بما فيها النواحي البيئية وعلى رب العمل أيضاً أن يوفر للمقاول كل تلك البيانات التي يحصل عليها رب العمل بعد تاريخ الأساس. والمقاول مسئول عن تفسير كل هذه البيانـــات. **البند رقم 4-12 "الظروف المادية غير المتوقعة** إذا واجه المقاول ظروف مادية معاكسة التي تعتبر من وجهة نظر المقاول غير متوقعة ، على المقاول أن يخطر المهندس في أسرع وقت ممكن. هذا الإخطار يجب أن يصف الظروف المادية ، حتى أن يقوم المهندس بفحص هذه الظروف، ويوضح الأسباب التي جعلت المقاول يعتبر هذه الظروف غير متوقعة ، وعلى المقاول أن يستمر في الأعمال مستخدماً القياسات اللائقة والمناسبة لهذه الظروف المادية ، ويجب أن يمتثل لاي تعليمات يعطيها المهندس وإذا شكل أي من هذه التعليمات تغيرات فيجب إعمال البند 13 (التغيرات والتعديلات).
القانون المصري	**مادة 80 في القانون رقم 98 لسنة 1989** يلتزم المقاول بأن يتحرى بنفسة طبيعة الأعمال وعمل كل ما يلزم لذلك من إختبارات وغيرها للتأكد من صلاحية المواصفات والرسومات والتصاميم المعتمدة وعلية إخطار الجهة الإدارية في الوقت المناسب بملاحظته عليها ويكون مسئولاً تبعاً لذلك عن صحة وسلامة جميع ما ورد بها كما لو كانت مقدمة منه. **مادة 651 في القانون المدني المصري** يضمن المهندس المعماري والمقاول متضامنين ما يحدث خلال عشر سنوات من تهدم كلى أو جزئي فيما شيدوه من مبان أو أقاموه من منشآت ثابتة أخرى وذلك ولو كان التهدم ناشئاً عن عيب فى الأرض ذاتها، أو كان رب العمل قد أجاز إقامة المنشآت المعيبة ، ما لم يكن المتعاقدان فى هذه الحالة قد أرادا أن تبقى هذه المنشآت مدة أقل من عشر سنوات. - ويشمل الضمان المنصوص عليه فى الفقرة السابقة ما يوجد فى المباني والمنشآت من عيوب يترتب عليها تهديد متانة البناء وسلامته - وتبدأ مدة السنوات العشر من وقت تسلم العمل ولا تسرى هذه المادة على ما قد يكون للمقاول من حق الرجوع على المقاولين من الباطن.
القانون الفرنسي	المسئولية عن الظروف غير الظاهرة الطبيعية المتعلقة بالأرض يجب ان يتحملها المقاول.
القانون الألماني	المالك يتحمل مخاطر الظروف غير الظاهرة في التربة التحتية.
القانون الأيطالي	في حالة الأحداث غير الظاهرة، يجب ا، تزيد تكلفة المشروع بالنسبة للوقت والمواد عن 10% من قيمة العقد قبل أن يحق للمقاول المطالبة بتعديل العقد بما في ذلك الوقت والسعر.
القانون النيوزلندي	يضمن المالك للمقاول قبل تقديم العطاء توفير كل المعلومات عن طبيعة الأرض المتعلقة بالأعمال التي يشتمل عليها العقد. ولكن لا يظمن المالك كفاية أو دقة هذة المعلومات ويكون المقاول مسئولاً عن تفسير كل هذه المعلومات لأغراض الأعمال المتعاقد عليها.
القانون الماليزي	على المقاول فحص وإختبار الموقع ومحيطه حتى يكون راضٍ بنفسه قبل تقديم العطاء.

وبناءً علية فإن هناك كثير من الأسئلة تحتاج الي إجابة عن أبحاث التربة وخاصة القانون المصري والكود المصري للأساسات، لذا نرجو منكم الإجابة على الأسئلة التالية:-

1. كيف ترى خطورة ظروف التربة غير الظاهرة في الموقع؟

(أ) عالية جداً ( ) (ب) عالية (*) (ب) متوسطة ( )

(أ) منخفضة ( ) (ب) منخفضة جداً ( )

2. هل تجد الكود المصري عملياً من ناحية تعاملة مع أبحاث التربة من الناحية التقنية؟

(أ) نعم ( ) (ب) لا ( )

3. هل يتم عمل أبحاث تربة بشكل مناسب في المشاريع التي تعملون بها؟

(أ) دائماً (*) (ب) غالباً ( )

(أ) أحياناً ( ) (ب) أبداً ( )

4. ما هو تكرار تطابق أبحاث التربة مع ما تجدونة في الموقع؟

(أ) دائماً ( ) (ب) غالباً (*)

(أ) أحياناً ( ) (ب) أبداً ( )

5. ما هو تكرار مواجهتكم لعيوب تربة غير ظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً (*)

(أ) أحياناً ( ) (ب) أبداً ( )

6. ما هو تكرار زيادة تكاليف المشاريع عن الميزانية المخطط لها نتيجة لمواجهة عيوب تربة غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً (*)

(أ) أحياناً ( ) (ب) أبداً ( )

7. ما هو تكرار إمتداد زمن المشاريع عن الزمن المخطط لها نتيجة لمواجهة عيوب تربة غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً (*)

(أ) أحياناً ( ) (ب) أبداً ( )

8. من واقع خبرتكم من هو المسئول عن ظروف التربة غير الظاهرة التي تطرأ خلال إنشاء المشروع؟

(أ) المالك ( ) (ب) المقاول ( )

(أ) المسئولية مشتركة ما بين المالك والمقاول بشكل ما (*)

9. ما هو سبب اختيارك لإجابة السئوال رقم (8)؟

المسئوليه يجب ان اتكون مشتركه لان المالك من مصلحته تقليل التكاليف قدر المستطاع والعكس لدى المقاول لحصوله على نسبه من اجمالى المشروع مثلا وفى نفس الوقت ليس من صلاحيات المقاول اخد القرار بعمل اعمال تربه اضافيه الا بموافقة المالك لذا يجب ان تكون المسئوليه مشتركه.

10. أذا كانت اجابتك للسئوال رقم (8) هي أن المسئولية مشتركة ما بين المالك والمقاول بشكل ما فما هي الطريقة المقترحة لمشاركة المسئولية بينهما ؟

أعتقد ان تكون مناصفه بين الطرفين.

11. ما هي إقتراحاتكم لتعديل القانون المصري لتحسينة في مجال أبحاث التربة لتفادي أخطار الظروف غير الظاهرة ؟

يجب التنبيه على هذه الاخطار بشكل اوضح ووضع العديد من الغرامات القويه للحد من الإستهتار بمجال ابحاث التربه والاعتماد المطلق على سابقه الخبره بمكان المشروع مقلا او العمل بمشاريع مماثله بدون عمل تغطيه كافيه لدراسات التربه.

12. ما هي الشروط المقترح إضافتها الي العقود لتغطية مسئولية ظهور الظروف غير الظاهرة ؟

أعتقد ان وجود ظهور الظروف غير الظاهرة مسئوليه كبيره وليس من المفترض ان يتحملها جهة او اكثر الا فى حالة اثبات ان ذلك نتيجه تساهل واستهتار من الجهات المسئوله ، حيث انه بفرض ان الجهات المسئوله قد ادت دورها على الوجه الاكمل وتم عمل جسات ودراسه للتربه يشكل وافى وتم استنتاج قطاعات للتربه فى العديد من الاماكن وعمل تقارير جيولوجيه للمكان ثم ظهرت ظروف جديده فلا يشترط فى العقد ان يتحمل احدهما (المالك والمقاول) المسئوليه فقد تكون نتيجه التصميم وعدم اختيار الارقام المناسبه لتمثيل خواص التربه وغيره.

بسم الله الرحمن الرحيم

إستبيـــــان

السيد:- مصطفى محمد عبدالله ابوزيد الوكيل

المهنة:- مهندس مكتب فني الشركة:- المقاولون العرب

أود إحاطتكم علماً بأني طالب في مرحلة الماجستير في الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري. وانا في مرحلة إعداد الرسالة البحثية لنيل درجة الماجستير في مجال إدارة المشاريع الهندسية والتي هي بعنوان:-

"Effect of Inadequate Site Investigation on the Cost and Time of Construction Projects"

"تأثير عدم كفاية ابحاث التربة على تكلفة وزمن مشاريع التشييد"

وبصفتكم أحد العاملين في هذا المجال في مصر فأن مشاركتكم بالإجابة على هذا الإستبيان بالمعلومات المناسبة يعتبر جزء مهم يُثري الموضوع ويجعله ذو فائده علمية.

ونحن شاكرين تعاونكم بالإجابة على هذا الإستبيان والذي لن يأخذ من وقتكم الثمين اكثر من ١٥ دقيقة.

ونؤكد لكم أن الغرض الوحيد لهذا الاستبيان هو للبحث العلمي وان المعلومات سوف يتم تحليلها ودراستها كوحده واحده.

المشرفون على الرسالة

أ.د. محمد إمـــام عبدالرازق

أستاذ إدارة المشاريع في قسم التشييد والبناء بكلية الهندسة والتكنولوجيا بالأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

د. حسام الدين حسني محمد

قسم هندسة التشييد في كلية الهندسة بجامعة الزقازيق

الباحث

م. علي حفظ الله البطل

معلومات عامة

الرجاء كتابة أو إختيار الإجابة المناسبة للأسئلة التالية:-

س (١):- متى كانت بداية عمل شركتكم في مجال الإنشاءات؟

ج (١):- (أ) اقل من ٥ سنوات ( ) (أ) من ٥ الي ١٠ سنوات ( )

(ج) من ١٠ الي ١٥ سنة ( ) (د) أكثر من ١٥ سنة (✓)

س (٢):- ما هو تصنيف شركتكم طبقاً للإتحاد المصري لمقاولي التشييد والبناء او ما يقابله؟

ج (٢) :- (أ) درجة أولى (✓) (ب) درجة ثانية ( )

(ج) درجة ثالثة ( ) (د) درجة رابعة ( )

(هـ) درجة خامسة ( ) (و) درجة سادسة ( )

س (٣):- ما هي نوعية المشاريع التي سوف تعتمد عليها للإجابة على الأسئلة؟

ج (٣) :- (أ) مشاريع عامة (✓) (ب) مشاريع خاصة ( )

مقدمـــة

الظروف الغير ظاهرة قد يكون لها تأثير على تكلفة و وقت المشاريع حيث أنها قد تمنع الأطراف من أداء التزاماتها التعاقدية أحياناً أو تجعل أداء هذة الإلتزامات أصعب أو أعلى تكلفة أحياناً أخرى.

لم تنص معظم القوانين والأكواد صراحة على من تقع مسئولية عمل أبحاث التربة ولكن حددت من هو المسئول عن اي ظروف أو عوامل غير متوقعه او مخفية. وبالتالي يكون من الطبيعي أن المسئول عن أي احداث او ظروف غير متوقعه هو المسئول عن التحري عن وجود هذة الظروف. ويلخص الجدول التالي نصوص بعض القوانين لبعض الدول التي حددت من هو المسئول عن الظروف غير المتوقعة.

الفيديك	**البند رقم ٤-١٠ "بيانات الموقع "** على رب العمل أن يضع تحت تصرف المقاول لمعلوماته قبل تاريخ الاساس ، كل البيانات التي يمتلكها والمتعلقة بظروف تحت سطح الأرض وهيدرولوجية الموقع، بما فيها النواحي البينية وعلى رب العمل أيضاً أن يوفر للمقاول كل تلك البيانات التي يحصل عليها رب العمل بعد تاريخ الأساس. والمقاول مسئول عن تفسير كل هذه البيانــات. **البند رقم ٤-١٢ "الظروف المادية غير المتوقعة** إذا واجه المقاول ظروف مادية معاكسة التي تعتبر من وجهة نظر المقاول غير متوقعة ، على المقاول أن يخطر المهندس في أسرع وقت ممكن. هذا الإخطار يجب أن يصف الظروف المادية ، حتى أن يقوم المهندس بفحص هذه الظروف، ويوضح الأسباب التي جعلت المقاول يعتبر هذه الظروف غير متوقعة ، وعلى المقاول أن يستمر في الأعمال مستخدماً القياسات اللائقة والمناسبة لهذه الظروف المادية ، ويجب أن يمتثل لاي تعليمات يعطيها المهندس وإذا شكل أي من هذه التعليمات تغيرات فيجب إعمال البند ١٣ (التغيرات والتعديلات).
القانون المصري	**مادة ٨٠ في القانون رقم ٩٨ لسنة ١٩٨٩** يلتزم المقاول بأن يتحرى بنفسة طبيعة الأعمال وعمل كل ما يلزم لذلك من إختبارات وغيرها للتأكد من صلاحية المواصفات والرسومات والتصاميم المعتمدة وعلية إخطار الجهة الإدارية في الوقت المناسب بملاحظته عليها ويكون مسئولاً تبعاً لذلك عن صحة وسلامة جميع ما ورد بها كما لو كانت مقدمة منه. **مادة ٦٥١ في القانون المدني المصري** يضمن المهندس المعماري والمقاول متضامنين ما يحدث خلال عشر سنوات من تهدم كلى أو جزئي فيما شيدوه من مبان أو أقاموه من منشآت ثابتة أخرى وذلك ولو كان التهدم ناشئاً عن عيب فى الأرض ذاتها، أو كان رب العمل قد أجاز إقامة المنشآت المعيبة ، ما لم يكن المتعاقدان فى هذه الحالة قد أرادا أن تبقى هذه المنشآت مدة أقل من عشر سنوات. - ويشمل الضمان المنصوص عليه فى الفقرة السابقة ما يوجد فى المباني والمنشآت من عيوب يترتب عليها تهديد متانة البناء وسلامته - وتبدأ مدة السنوات العشر من وقت تسلم العمل ولا تسرى هذه المادة على ما قد يكون للمقاول من حق الرجوع على المقاولين من الباطن.
القانون الفرنسي	المسئولية عن الظروف غير الظاهرة الطبيعية المتعلقة بالأرض يجب ان يتحملها المقاول.
القانون الألماني	المالك يتحمل مخاطر الظروف غير الظاهرة في التربة التحتية.
القانون الأيطالي	في حالة الأحداث غير الظاهرة، يجب ا، تزيد تكلفة المشروع بالنسبة للوقت والمواد عن ١٠% من قيمة العقد قبل أن يحق للمقاول المطالبة بتعديل العقد بما في ذلك الوقت والسعر.
القانون النيوزلندي	يضمن المالك للمقاول قبل تقديم العطاء توفير كل المعلومات عن طبيعة الأرض المتعلقة بالأعمال التي يشتمل عليها العقد. ولكن لا يظمن المالك كفاية أو دقة هذة المعلومات ويكون المقاول مسئولاً عن تفسير كل هذه المعلومات لأغراض الأعمال المتعاقد عليها.
القانون الماليزي	على المقاول فحص وإختبار الموقع ومحيطه حتى يكون راضٍ بنفسه قبل تقديم العطاء.

وبناءً علية فإن هناك كثير من الأسئلة تحتاج الي إجابة عن أبحاث التربة وخاصة القانون المصري والكود المصري للأساسات، لذا نرجو منكم الإجابة على الأسئلة التالية:-

١. كيف ترى خطورة الظروف غير الظاهرة في الموقع؟

(أ) عالية جداً ( ) (ب) عالية (✓) (ب) متوسطة ( )

(أ) منخفضة ( ) (ب) منخفضة جداً ( )

٢. هل تجد الكود المصري عملياً من ناحية تعاملة مع أبحاث التربة من الناحية التقنية؟

(أ) نعم (.) (ب) لا (✓)

٣. هل يتم عمل أبحاث تربة بشكل مناسب في المشاريع التي تعملون بها؟

(أ) دائماً (✓) (ب) غالباً ( )

(أ) أحياناً ( ) (ب) أبداً ( )

٤. ما هو تكرار تطابق أبحاث التربة مع ما تجدونة في الموقع؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً (✓) (ب) أبداً ( )

٥. ما هو تكرار مواجهتكم لعيوب غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً (✓) (ب) أبداً ( )

٦. ما هو تكرار زيادة تكاليف المشاريع عن الميزانية المخطط لها نتيجة لمواجهة عيوب غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً ( )

(أ) أحياناً (✓) (ب) أبداً ( )

٧. ما هو تكرار إمتداد زمن المشاريع عن الزمن المخطط لها نتيجة لمواجهة عيوب غير الظاهرة في المشاريع التي عملتم بها ؟

(أ) دائماً ( ) (ب) غالباً (✓)

(أ) أحياناً ( ) (ب) أبداً ( )

8. من واقع خبرتكم من هو المسئول عن الظروف غير الظاهرة التي تطرأ خلال إنشاء المشروع؟

(أ) المالك ( ) (ب) المقاول (✓)

(أ) المسئولية مشتركة ما بين المالك والمقاول بشكل ما ( )

9. ما هو سبب اختيارك لإجابة السئوال رقم (٨)؟

سبب اختياري لإجابة السؤال رقم (٨) هو ان المقاول مسئول مسئولية كاملة عن الاختبارات والدراسات الخاصة بالمشروع.

١٠. أذا كانت اجابتك للسئوال رقم (٨) هي أن المسئولية مشتركة ما بين المالك والمقاول بشكل ما فما هي الطريقة المقترحة لمشاركة المسئولية بينهما ؟

١١. ما هي إقتراحاتكم لتعديل القانون المصري لتحسينة في مجال أبحاث التربة لتفادي أخطار الظروف غير الظاهرة ؟

١٢. ما هي الشروط المقترح إضافتها الي العقود لتغطية مسئولية ظهور الظروف غير الظاهرة ؟

* يقدر قيمتها المقاول والاستشاري والمالك حسب الأسعار السائدة في السوق للأعمال المماثلة من نفس مستوى المواصفات على ان يتم الاتفاق بين الاطراف المذكورة بشرط الا يؤخر تنفيذ العمل بسبب أي خلاف يقوم بين هذه الأطراف ولا يمكن بأي حال من الأحوال ان تزيد المبالغ التي تدفع للمقاول مقابل هذه الأعمال عن المبالغ التي يحددها المالك والاستشاري والمقاول طبقاً للاسعار السائدة في السوق.

المستخلص

المعلومات الصحيحة هي أساس أيّ تصميمٍ هندسي. و في أي نظامٍ هندسي، تعتمد دقة مخرجات هذا التصميم على دقة وصحة مدخلاته. و تعتبر عدم المعرفة بخواص التربة واحدةً من أهم أسباب انهيار المنشآت الهندسية، وعدم المعرفة بخواص التربة التي سوف يتم إنشاء المشروع عليها قد تتسبب في تجاوز تكلفة المشروع للقيمة المتوقعة له، وقد تتسبب أيضاً في زيادة وقت المشروع عن المدة المحددة له. كما أنّ عدم كفاية أبحاث التربة تعتبر أهم مسبّبات الحصول على تصاميم غير اقتصادية،أو تأخير أوقات المشاريع عن المدة المحددة لها ،أو نشوء النزاعات في المشاريع الهندسية.

و تلعب اختبارات التربة دورًا مهمًّا في تزويد مهندسي المشروع بالمعلومات الصحيحة عن التربة للوصول الى التصميم الأمثل لأساسات المنشأ الهندسي. كما تهدف أبحاث التربة إلى تقليل عدم المعرفة أو عدم اليقين بظرف التربة، وذلك بعمل اختباراتٍ حقليةٍفي الموقع ومعمليّةٍ لعيّناتٍ من تربة الموقع، بغرض الحصول على الخواص الصحيحة للتربة، وذلك لعمل تصميمٍ مناسبٍ لأساسات المشروع الهندسي.

و حقيقةً، فإنّ عدم كفاية أبحاث التربة، قد تنتج عنها خواص لا تمثل حقيقةً خواص تربة الأرض التي سوف يقام عليها المشروع، وبالتالي قد يكون التصميم غير اقتصادي أو أقل من التصميم الذي يحتاجه المنشأ، ممّا قد يسبّب انهيارًا كليًّا أو جزئيًّا للمنشأ الهندسي. لذا يتمثل الغرض الرئيسي لهذا البحث الهندسي في معرفةتأثير تغير نطاق أبحاث التربة على تكلفة وزمن المشروعات الإنشائية. إذ أنّه بمعرفة قيمة هذا التأثير قد يتم التوصل الىاستنتاجٍ عن أهمية أبحاث التربة ومعرفة أنّ تكلفة أبحاث التربة تعتبر صغيرةً مقارنةً بتكلفة العواقب التي قد تنشأ نتيجة الإهمال أو التقصير في عملها.

و كما أنّ الظروف غير الظاهرة بالموقع قد تؤثر سلباً على تكلفة و زمن المشاريع الإنشائية. فإنّهاقد تمنع أحياناً أطراف العقد من أداء التزاماتهم التعاقدية، أوتعرقل أداء الالتزامات التعاقدية في أحيانٍ أخرى.

و يعتبر عقد الإنشاء هو المرجع الأول عند حصول أي خلاف بين أطراف العقد. و عند صياغة العقد الهندسي يجب مراعاة عدم تعارضه مع قوانين البلد المزمع عمل المشروع بها. و عليه فالغرض الآخر لهذا البحث الهندسي كمن في البحث عن كيفية التعامل مع موضوع أبحاث التربة في القانون المصري والعقود الإنشائية في مصر.

الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحرى

كلية الهندسة

قسم التشييد والبناء

تأثير عدم كفاية أبحاث التربة على تكلفة وزمن مشاريع التشييد

إعداد

علي حفظ الله علي البطل

رسالة مقدمة للأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري لإستكمال متطلبات نيل درجة

الماجستير

في

هندسة التشييد والبناء

إشراف

أ.د. محمد إمام عبدالرازق

أستاذ التشييد والبناء

الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

أ.د. حسام الدين حسني محمد

أستاذ مساعد في إدارة المشروعات

جامعة الزقازيق

2013