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UNIVERSITI TEKNOLOGI MALAYSIA

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JUDUL: **THE PROBLEMS IN THE APPLICATION OF THE MICROPILE FOUNDATION SYSTEM IN MALAYSIA**

**SESI PENGAJIAN: 2006/2007**

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# THE PROBLEMS IN THE APPLICATION OF THE MICROPILE FOUNDATION SYSTEM IN MALAYSIA

HALIMMI BIN HASHIM

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Science (Construction Management)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

MAY, 2007

I declare that this project report entitled "**THE PROBLEMS IN THE APPLICATION OF THE MICROPILE FOUNDATION SYSTEM IN MALAYSIA**" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 10th May 2007

This project report is dedicated to my early mentors, Ir. Hope Thevaraj and Dato' Ir. Syed Muhammad Shahabudin to whom I am professionally inspired, to my precious mother and father and both my parents in-law. And most of all I devote this, to my wife Aida Nazlene and my children Tahira, Yasar and Qayyum.

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HALIMMI BIN HASHIM

# ABSTRACT

The micropiling concept is relatively young. The system which evolved in Europe in the 1950s, introduced to the United Kingdom in 1962 and to North America a decade later in 1973 was first applied in Malaysia in the early 1980s. The concept as a foundation system in Malaysia has gained acceptability in difficult ground condition and treacherous limestone areas. However, the current micropile design and construction practices in Malaysia is very fragmented, unguided and are generally independently reliant on the experience and knowledge of the specialist contractor or designer only. The aim of this study is to review the current practice of micropile system in Malaysia with regard to the limitations and problems of its application and identifying the improvement proposal. Literature reviews, industry observations and expert consultations were carried out to investigate the present and past practices in North America, Europe and Malaysia. The studies were sub-divided into different categories of the micropile practices differentiated by planning and design Practices, and construction practices. The Expert Panel Survey on a target group of experts had confirmed the deficiencies and problems identifying a state of lacking and fragmentation in certain aspects of the micropile practices in the country. This subsequently reinforced the need by the Industry Survey to determine and validate areas of weaknesses and obtain ratings on proposed change factors for the improvement of practice standards. The study showed that there is in general a gap existing between the level of analytical understanding and that of performance knowledge and construction excellence. It further confirmed the need to regularise and to standardise the industry, and to educate. While ways, methods and some industry improvement factors to drive positive changes were tested and determined, it was also found that the degree for improvement that is required varies among the component aspects of its current planning, design and construction practices.

# ABSTRAK

Penggunaan konsep cerucuk mikro adalah agak baru. Sistem ini diwujudkan di Eropah pada awal tahun 1950an. Ia mula diperkenalkan di United Kingdom pada tahun 1962 dan di Amerika Utara satu dekad kemudian. Di Malaysia sistem cerucuk Mikro ini mula digunakan pada awal tahun 1980an. Sistem cerucuk ini diterima di Malaysia sebagai penyelesaian terhadap masaalah kerja asas di kawasan substruktur yang sukar dan kawasan batu kapur. Walaupun sistem ini sudah diterima pakai tetapi masih belum wujud satu garispanduan piawai yang lengkap untuk dirujuk dalam amalan rekabentuk dan pembinaannya. Sistem rekabentuk cerucuk mikro pada masa ini sangat bergantung kepada pengalaman dan kepakaran inidividu perunding dan kontraktor. Oleh itu kajian ini telah dijalankan dengan tujuan untuk mengkaji masaalah yang wujud dalam amalan rekabentuk dan pembinaan sistem cerucuk mikro ini. Diantara fokus dalam kajian ini termasuklah untuk mengkaji masaalah dan kelemahan dalam aplikasi sistem cerucuk ini serta mengenalpasti kaedah yang boleh digunakan untuk membantu meningkatkan keberkesanan penggunaan sistem ini. Metodologi utama yang digunakan dalam kajian ini adalah kajian literatur, temubual dengan panel pakar yang mempunyai pengalaman luas dalam sistem cerucuk ini serta pengedaran borang soal selidik. Hasil daripada kajian di peringkat awal mendapati bahawa panel pakar telah bersetuju bahawa sememangnya wujud masaalah tiada panduan dan piawai yang jelas yang dapat dirujuk dalam amalan rekabentuk dan pembinaan sistem cerucuk mikro dinegara ini. Selain dari itu, juga didapati terdapat masaalah dalam menghubungkait diantara kaedah analisa rekabentuk dengan prestasi sebenar yang dicapai oleh cerucuk mikro ini dalam pembinaan. Kajian ini juga telah mengenalpasti faktor yang penting untuk memperbaiki lagi amalan penggunaan sistem cerucuk mikro ini. Sebagai rumusan adalah sangat penting bagi industri pembinaan di Malaysia mengwujudkan satu sistem rekabentuk piawai yang dapat dirujuk dan dijadikan panduan oleh para perunding dan kontraktor supaya penggunaan cerucuk mikro ini lebih selaras samada untuk peringkat rekabentuk atau pun pembinaannya.

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| | | |
|---|---|---|
| **A** | - | Surface area of rock/grout bond |
| $\mathbf{A}_c$ | - | Nett grout x-sectional area |
| $\mathbf{A}_g$ | - | Gross x-sectional area of the micropile |
| $\mathbf{A}_s$ | - | Steel core or reinforcement x-sectional area |
| $A_p$ | - | Area at bottom of the pile based on a diameter *D* (if the construction procedure produces an increase in diameter) |
| c | - | Cohesion or strength intercept of the assumed straight line Mohr envelope |
| $c_a$ | - | Adhesion between pile and soil independent of the normal stress acting on the shaft |
| $C_u$ | - | Average undrained shear strength over the bond length |
| *D, d* | - | Gross diameter of the micropile |
| $D_s$ | - | Diameter of rock socket |
| $E_{grout}$ | - | Modulus of elasticity, grout |
| $E_{rock}$ | - | Modulus of elasticity, rock |
| $f_s$ | - | Unit skin friction/ unit shaft resistance |
| **f** | - | Allowable rock/grout bond strength |
| $\mathbf{f}_y$ | - | Yield stress of steel core or reinforcement |
| $\mathbf{f}_{cu}$ | - | Grout characteristic strength |
| *FS* | - | Factor of Safety |
| I | - | Dimensionless coefficient based on the nominal diameter of the micropile (drilling diameter) |
| $k_p$ | - | Coefficient for point bearing which depends on soil type |
| $k_{sp}$ | - | Empirical bearing capacity factor based on the spacing of the discontinuities of the rock |
| K | - | Coefficient representing the average interaction between the micropile and the soil for the whole length (pile-soil adherence: based on soil consistency) |
| $K_o$ | - | Coefficient of at rest lateral pressure |
| $K_s$ | - | Coefficient of skin pressure |
| $K_p$ | - | Coefficient of passive earth pressure [ = $\tan^2 (45+ \phi/2)$] |
| *L* | - | Bond length in soil only |

| | | |
|---|---|---|
| $L_s$ | - | Pile rock socket length |
| $L_T$ | - | Total length of pile |
| n | - | Factor which is affected by ¶ |
| N | - | Standard Penetration Test (SPT) value/300mm penetration |
| $N_c$* | - | Dimensionless bearing capacity factors as a function of the soil friction angle $\phi$ |
| $N_s$ | - | Dimensionless bearing capacity factors as a function of the soil rigidity index $I_r$ |
| $\phi$ | - | Angle of shearing resistance granular soil |
| $\phi'$ | - | Effective angle of shearing resistance granular soil |
| $\phi_r$ | - | Angle of shearing resistance of the rock mass |
| $p_i$ | - | Grouting pressure |
| $p_l$ | - | Limit pressure of the soil pressure of soil at the bottom of the pile found with the Ménard pressuremeter test |
| $q_p$ | - | Unit point resistance/unit base resistance |
| $\mathbf{q}_u$ | - | Unconfined compressive strength of rock |
| $q_s$ | - | The normal stress acting on the foundation shaft which is conventionally related to the effective vertical stress $q_v$ [ = $K_s.q_v$] |
| $q_{s1}$ | - | Lateral friction which depend on $p_1$ and on the type of soil; values can be obtained from graphs of $q_s$ vs $p_l$ |
| $q_v$ | - | Effective vertical stress |
| $Q_p$ | - | Pile end bearing capacity |
| $Q_s$ | - | Pile total shaft friction |
| $\mathbf{Q}_a$ | - | Allowable load or design working load |
| $\mathbf{Q}_u$ | - | Pile ultimate structural capacity |
| $Q_L$ | - | Ultimate geotechnical capacity |
| $QP_L$ | - | Limit point bearing capacity |
| $QS_L$ | - | Limit side resistance |
| tan d | - | Coefficient of friction between soil and shaft [= tan $\phi'$ for piles of normal roughness] |
| $t_{ult}$ | - | Ultimate rock skin friction/rock-grout bond value |
| T | - | Pile grout bond with granular soil |
| $T_{ult.}$ | - | Ultimate bearing capacity |
| $\alpha$ | - | Pile/soil adhesion factor which varies between 0.6 and 0.8 for micropile design |
| $\sigma_o$ | - | Mean normal effective ground stress related to the effective vertical stress [= 1/3 $(1+2K_o)q_v$] |

$\sigma_r$ - Failure radial stress

¶

- drilling technique (rotary percussive with water flush),
- depth of overburden,
- fixed anchor diameter,
- grouting pressure in the range 30 to 1000 kPa ,
- in situ stress field, and
- dilation characteristics of the soil

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*"Lives of great men all remind us. We can make our lives sublime and departing leave behind us footsteps on the sands of time..."*
**Henry Wadsworth Longfellow**

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Unlike piling systems such as pre-cast reinforced concrete or spun concrete piles which has long been established and guided by well defined practice codes, the micropile is in contrast a non-proprietary system which is largely the responsibility of the Engineer to design and specify. The dearth of documented guidelines, rules or conduct definition in its practice has placed its applications in this country on a pedestal that is subjective and arbitrary and dependent largely on the designer's own and independent past experiences and perception of the system, and paired by the unregulated and liberal choices of construction methods by the contractor. Neoh (1996) had commented that the current micropile design and construction practice is considered to be very empirical and are generally reliant on the experience and knowledge of the micropile specialist contractor for calculation and specification. Empiricism is in fact the philosophy by which geotechnical engineering is practiced worldwide. While micropile practices are not expected to be of any exception, it is without an acknowledged and established empirical rule, unlike others. Currently, reliable designs are based on sound judgment and experience rather than the truth, a situation that does not bode well for the industry.

The concept of the micropile system as a deep foundation system in Malaysia has gained acceptability in difficult ground and treacherous limestone areas in contrast to the traditional steel piles or bored piles. This is said to be mainly due to technical superiority in respect of fast installation while providing reliable capacity. It has grown since the early 1980s amidst the absence of a commonly accepted industry practice guideline which could serve as a benchmark for both regulation of good practice as well as an authority in cases of disputes and litigations. The lack of common ground on acceptable practices has also resulted in an array of problems, some technical and the others professional, arising from arguable and inconsistent opinions and criteria in application.

The Partnership for Advancing Technology in Housing (PATH) in 2002 stated that as for most technologies, considerations of practice regulations are addressed after the technology is already in the marketplace. Similarly, this applies to micropile. In Malaysia, only Jabatan Kerja Raya (JKR) has been known to have formulated a brief design and practice notes intended for in-house use only. The system has enjoyed technology deployment for over 20 years.

Taking a technology from idea through development and deployment to market acceptance is complex and requires many activities. The use of micropile has seen the reverse of these where there was technology acceptance prior to research and development, therefore giving rise to the approach of "predict and control". The practice needs to be better defined, documented and regulated, in order to ensure that acceptable industry standards are achieved, kept sustainable and evolving.

## 1.2 Problem Statement

Neoh (1996), stated that the choice of the formula used in piling and foundation designs depends on the designers' individual preference and experiences and that the resulting computations must be checked by senior geotechnical engineers who must have several years of experiences to ensure that designs are reasonable. Problems arises when designers lacks the design experience and knowledge, amounting to working beyond an area of competency against the Board of Engineers Malaysia, Code of Ethics (Revision 2002). The unchecked design is further exacerbated by contractors who are neither engineers nor possessing the necessary engineering and skills to notice design flaws. Thereon, there persist the errors of ignorance and inexperience creeping through the stages of planning, design and procurement and construction phases until these errors are arrested and identified at an advanced stage, sometimes at substantial cost and delays.

Micropiles have been universally accepted as the least understood of all the piling systems, and even so called ‘senior geotechnical engineers’ lacks the level of knowledge to be effective technical adjudicators. The United States Federal Highway Administration (2000) reported that most United States’ public agencies and consulting engineers presently have little or no knowledge regarding micropiles and their application. At the moment, excellent piling supervisors or contractors are equally as crucial as expert pile designers for the successful implementation of micropile works. The understanding of all piling principles is requisite to expert pile designers and supervisors. An ignorant piling supervisor or contractor can turn a sound pile design into a nightmare, but an experienced supervisor or contractor can prevent poorly conceived pile design from becoming a disaster (Neoh, 1996). British Standards Institution, BS 8004 recommends that a competent person, properly qualified and experienced, should be appointed to supervise piling operations. This person should be capable of recognising and assessing any errors or potential danger as they arise that may require a change in design and/or construction technique.

The implementation of the micropile technology in Malaysia, have existed on a platform roughened by the lack of practical design and construction guidelines. In place of a time consuming learning curve, ‘guidelines’ could help to ‘smoothen’ out the prevalent overall ‘roughness’ of knowledge in a much shorter period. Since the early 1980’s when Malaysia first adopted this foundation concept, there is still no dedicated and documented design guidelines, procedures or codes for micropile use and practice in Malaysia despite the ambiguities and anomalies among designers.

The absence of standards and the lack of analytical knowledge in its design, characteristics and nature of behaviour and performance, has resulted in the use of:

- Standardised, repetitive and extravagant designs appearing in Tenders.
- Multitudes of unlikely design variants and material usage contradicting the requirements of various relevant codes, and
- The use of patchy or sometimes non-existent material specifications.

Todate most Malaysian Engineers still has a superficial knowledge of an appropriate practice philosophy that lead to practitioners widely opting to practice by:

- the duplication of designs and construction specifications inappropriate to site and sub-soil condition;
- the reproduction of higher capacity existing/previous designs and the adoption of these designs for lower capacity need;
- over designed details and over specification (erring on the safe side);
- under designed details and under specification (total lack of knowledge and experience);
- a lack of the knowledge of construction material properties required resulting in the, usage of wrong materials inappropriate to construction techniques and pile dimension (constructability issue);
- inability to predict and forecast expected performance and results of their designs and specifications; and
- misconception of the system's capability (by MLT or otherwise) due to the absence of any understanding of its limitations.

The minimalism approach in design has at times resulted in very wasteful designs where at times the cost of piling could have been reduced by 40%. Full trust on the capability of the system without any consideration of its limitations has compounded the problem.

Design adjustments are required to counter the effects of level of stresses that are in addition governed by serviceability limits (pile length differentials), Maximum slenderness ratio (maximum elastic compression), low slenderness ratio (excessive pile stresses) and negative skin friction (additional loads). Unless better knowledge and understanding is acquired, uncertainties will prevail and very safe decisions will continue to be taken based on experience only which is most likely to have excessive tendencies, costing more than what is necessary. The lack of both design and performance behaviour knowledge of the system for over 20 years, has forced the micropile design to continue to be based on the approach of “predict and control” as an industry norm.

The main issues confronting the Malaysian micropile practice were:

- Competent knowledge and understanding confined only to a very few.
- Proliferation of differing concepts and design philosophies.
- Absence of local research and interest in academia.
- No set standards and guidelines as yet for practice.

The source of this state of backwardness could be traced to the comments by Neoh (1996) of Institut Latihan dan Penyelidikan Kerja Raya Malaysia, that the present day micropile design and construction practice still remains empirical due to the lack of research data. The state of affairs could be generalised as follows:

1. Local and current micropile design and construction practice is considered to be very empirical.
2. Reliable designs made from design decisions based on judgement and experience rather than the truth.
3. Inept practice by designers – often requires intervention
4. Generally reliant on the experience and knowledge of the micropile specialist contractor's. When ‘cheap’ and non-specialist sub-contractors are paired with ‘inept’ designs, disaster occurs.

5. Lack of scientific knowledge prevents optimised designs and construction – uneconomical.

6. Faulty judgement and lack of experience results in construction problems and cost overruns as a documented "truth" has yet to exist.

7. No dedicated standards exist. No defined practice method/s; requirements are derived from many different codes and standards.

8. Too many design methods in use (designs are independent and subjective).

9. Construction methods vary and are driven by commercial interest – not technical or cost considerations.

The United States Federal Highway Administration in its FHWA Publication No: FHWA-RC-BAL-04-0015 stated that the implementation of micropile technology on U.S. transportation projects has been hindered by the lack of practical design and construction guidelines, a situation seemingly familiar to Malaysia.

## 1.3 Objectives

This aim of this study is to review and expose current concepts, methods and weaknesses of local micropiling practices by probing queries into aspects of the practices and revealing its actual status and condition. It was also aimed at identifying the level of weaknesses of the various aspects of the practices, the critical areas and thereon the determination and suggestion of change factors for improvements. The information gained by the study could lead towards further efforts for an overall improvement of the state-of-practice for micropiles, identify the virtues as well as limitations in order to arrive to a benchmark representing best practices and good standards, technologically and economically.

The objectives of this study are as follows:

(i) To evaluate and perform a review of current Malaysian Practices in the use of the micropile piling system.

(ii) To determine the problems and limitations of current practices.

(iii) To identify possible changes for improvement to practice standards (design and construction) for micropile foundation.

## 1.4 Scope of the Study

Each of the numerous participants in the process of planning, (concept and technological, economic and feasibility studies), designing, (preliminary and detailed engineering), financing, (procurement), constructing and, operating physical facilities (start-up, operation, utilisation) has a different perspective on overall project management for construction (Hendrickson, 1998). The focus of attention for this study is not on all of the components of a project life cycle, but to identify strengths, weaknesses, problems and limitations in the steps and activities employed in direct application of the micropile system, namely in the stages for

i. planning and design practices i.e. (conceptual, technological, economic and feasibility studies) and designing i.e. (preliminary and detailed engineering), and

ii. construction operation practices (drilling, reinforcing, grouting, pile finishing).

## 1.5 Brief Research Methodology

The methodology used in conducting this study were through identification of the problem structure from literature search, industry observations and consultations with experts, followed by an expert panel structured questionnaire survey with local professionals of proven expertise in micropile design and construction to largely establish a general overview of the state-of-practice of the micropile technology and verify current problems and limitations facing the practices. The study was finally capped by an industry survey through structured questionnaires directed to a wider spectrum of respondents comprising users and practitioners of the system. The industry survey was intended at gaining some direction for changes and improvement to current practices in order to address the problems and limitations associated with micropile practices.

The overall sequence of research process undertaken for the study is shown in figure 1.1.

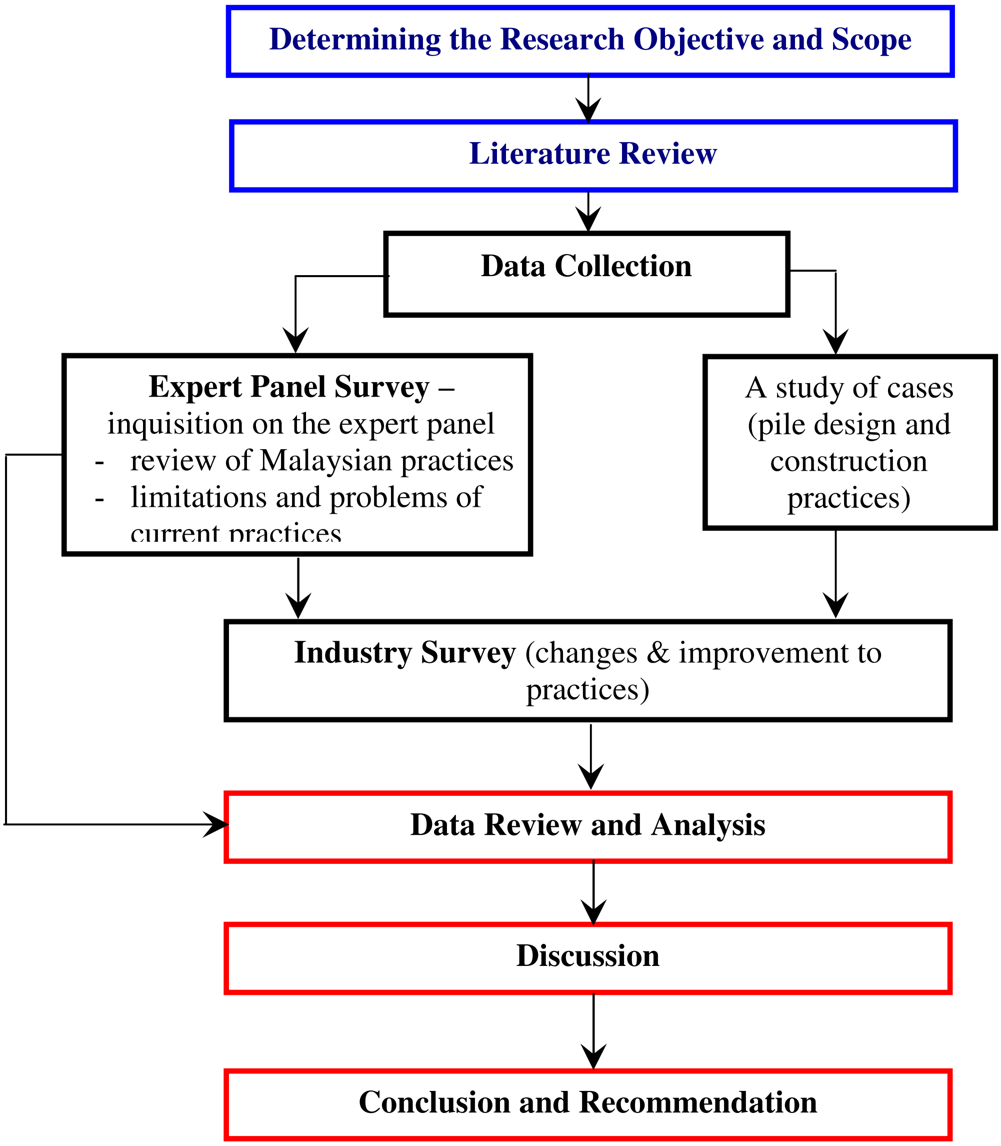


**Figure 1.1 -** Research Methodology Flowchart

## 1.6 Significance of the study

In Malaysia, micropiles have been used mainly as elements for structural foundation support to resist static and lateral loading conditions, and as in-situ reinforcements for slope and excavation stability. Many of these applications have been for transportation, building structures and as slope failures permanent remedies.

The lack of standardisation in practice, todate has resulted in a less than professional manner with which micropiles has been applied in Malaysia. A loosely defined set of rules is detrimental to professionalism and ethics. The JKR has drawn their own guidelines for in-house guidance based on their own review of case studies of past projects (Neoh, 1994). However, this may be regarded as still being very general and lacks the depths of knowledge to be justified as a standard.

The importance and significance of this study is to gain a better insight into the present day micropile foundation practices. Information obtained can be utilised to help alleviate the problems of weaknesses and anomalies of approaches and concepts. In addition, the study design can be implemented as a part of an future extended study whereby the limitations and uncertainties in the current state-of-the-practice need to be evaluated with greater rigour and further research needs be identified. Eventually, the product of the efforts should be a national and industry regulated manual of design and construction guidelines directed for use by practicing engineers, government agencies, geotechnical and structural engineers.

## 1.7 Limitations of the study

The limitations for the study relates mainly to issues pertaining to human factor and time constraints. The scope of this study had to be restricted to issues of general practices only without touching on finer details of the aspects of the practices which could be a huge insurmountable task given the amount of design and construction elements linked to the design and construction of micropiles.

Limitations to the study come in the form of:

a. Limited number of respondents available

b. Apprehension in answering survey questions

c. Numerical analysis - depths of research and scientific studies required

Most practicing engineers and technicians, however, are aware of the nature and attributes of the micropile. However, very few are aware of the technicalities and principles behind its design and fewer still are the number of engineers who are conversant with the design principles, material usage, construction processes, and the relationship of these to the eventual performance and behaviours of the micropiles. There is another group of people involved with the technology whose knowledge is confined to the drilling and installation of the micropile only. These are the works contractors or sub-contractors who are non-engineers or professionals from other disciplines who lacks the knowledge of engineering principles. Often, they have dangerously conceived engineering perceptions on the workings of the micropile.

This section illustrates a situation where the number of qualified respondents for this study would be limited. In ensuring that all survey results have 'quality and validity', only respondents fulfilling all of the criteria such as experience in micropiles, formal tertiary technical education and are engineers, geologist or quantity surveyors, has some micropile design knowledge and at least some micropile construction knowledge were invited to participate in the study.

Excluded from participation in this study were the many works contractors or sub-contractors who are knowingly just specifications and shop drawing observers. They lack the engineering training to allow critical thinking to be applied on engineering issues for survey and study reliability and validity.

One observation made is the tendency to treat the survey questionnaires as a test of competency by the respondents, hence apprehension and delays in response. With an overwhelming majority of respondents with work experiences more than 15 years, most are weary of protecting their professional reputation and places strong emphasis in trying to answer 'correctly'.