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EFFECTIVENESS OF PROFESSIONAL ADVICE IN GEOTECHNICAL ENGINEERING – SOME SRI LANKAN EXPERIENCES

EFFICACITE DES CONSEILS PROFESSIONNELS EN GENIE GEOTECHNIQUE – QUELQUES EXPERIENCES AU SRI LANKA

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SYNOPSIS

This paper considers the need for imparting professional advice effectively in the field of geotechnical engineering in Sri Lanka. The authors discuss the shortcomings in the professional practice of geo-technical engineering at present with reference to several case histories. They also discuss, the factors that will enable professional advice to be effective.

INTRODUCTION

When providing professional advice in geotechnical engineering for the designing and construction of civil and building structures, three important factors have to be considered. They are :

- Designing and constructing geotechnical structures to meet the structural requirements of the project.
- Selecting the most cost effective design and construction option.
- Completing the design and the construction to meet the client's time targets.

In most projects, professionals who provide consultancy services in the geotechnical field do not give adequate attention, most of the time to the above factors due to many reasons. As a result, during the construction and the operation of the project, the client faces one or more of the following unacceptable situations :

- Structural failures
- Unallowable settlements
- Cost and time over-runs

PRESENT PRACTICE

Standards and Specifications

Standards, Specifications and Codes of Practice in Civil Engineering define the basic framework within which all planning, design and construction works are carried out. The National Standards for the industry, commerce and trade are formulated by the Sri Lanka Standards Institution. Though the Sri Lanka Standards Institution Act provides for making the adoption of these National Standards compulsory, in practice these standards are considered to be intended for voluntary adoption by concerned parties. In Sri Lanka, for historical reasons, British Standards and Codes of Practice are in use for civil engineering works. However, steps have been taken to prepare our own Codes of Practice in

certain fields. The Institute for Construction Training and Development is presently engaged in the preparation of Codes of Practice for Site Investigations for foundations.

Legal Provision

Unlike in many other countries, there is no law in Sri Lanka which requires reports on ground conditions as a precondition to the grant of approval by a State authority for construction of buildings in towns and cities. There is no special law which controls or prevents the construction of buildings in close proximity to existing buildings. However there is a law which protects roads and road reservations from such construction.

A number of cases have been reported from towns and cities of distress caused to existing structures due to construction activity in the adjoining property. Litigation in courts in these disputes has been a long drawn out process and often compensations for grieved parties are worked out through arbitrations. Many of these problems could have been avoided if the construction of new structure adjoining existing structures had been carried out with the advice of competent professionals. Since the owners are ignorant of such implications, they are reluctant to spend money on technical advice and finally end up paying more, due to these mishaps.

In some areas in the city of Colombo, where soft deposits of clay and fine sand are present, many cases have been reported of the cracking or failure of the existing buildings. This was due to excavations for foundations or construction of buildings being in close proximity to the existing buildings. The owners of existing buildings have to either obtain an injunction from judicial courts to stop the construction or claim compensation for the damage caused. Had proper professional advice been obtained at the stage of planning and designing of new buildings such problems could have been avoided.

In the central hilly regions of Sri Lanka, a number of cases have been reported where cutting the slope for construction of a house had caused distress to the house lying above in the adjoining property. Even stable hill slopes had been made unstable due to such constructions. To avoid such distress, legislation should be introduced to manage the construction on hill slopes so that the controlling State Authority can ensure the stability of the hill slopes and the safety of adjoining structures before granting approval for such construction.

Cost Optimization in Design

It is very rarely that designers do a comprehensive cost analysis in different foundation options in order to select the best cost effective design to meet the required standards. There are three major reason for this deficiency :

- not maintaining cost data on previously completed projects for future use.
- inadequate site investigation to consider more options.
- designs being done most of the time, under time constraint.

Furthermore, the authors have observed that most of the foundation structures are oversized due to inadequate site investigation, time constraints for designing and lack of professional advice where it is required.

In Sri Lanka, it is very rarely that clients obtain professional advice in designing and construction of foundations for single storied buildings. As a result, most of the foundations of single storied buildings can be categorized as either over-designed or under-designed foundations.

CASES AND COMMENTS

Supervision on Site Investigation

In Sri Lanka, results of Standard Penetration Tests (SPT) carried out in bore holes are generally used to design shallow foundation or piles in sand. Owing to insufficient care in carrying out these tests in areas which have deposits of fine sand and high water tables, low SPT values have been recorded and soil consultants have recommended deep foundations in areas where shallow foundations could have been used economically. This has been reported in some investigations carried out in the western part of Colombo district where layers of fine sand and coarse sand in a dense state lie on bedrock. One such case is described here.

For the construction of a housing complex in the city of Colombo consisting of three towers each seventeen storeys high, a local firm carried out the site investigation. Three bore holes were drilled at the site up to bedrock level which was encountered at depths varying from 19m to 23m. The investigation showed that the site consisted of a peat and clay layer sandwiched between a fine sand layer on the top and a coarse sand layer at the bottom which sat on the basement rock. The peat and clay layer was about 2m thick lying at depths varying from 2m to 12m in the site. The ground water table was found to lie at a depth of about 2m below ground level. The SPT values determined during these investigations for the sand layers were low indicating that the towers would have to be supported on piles resting on the bedrock.

It was suspected that special care had not been taken during the drilling to prevent blowing of the sand into the bore holes, resulting in low SPT values. The

consultant for the project which was a local firm, got ten bore holes drilled in the site under their careful supervision. The SPT values determined during these investigations for the sand layers were high and generally consistent around the site. The consultant decided to support the three towers of the housing complex on raft foundations to be founded at a depth of 3.3m below ground level and to carry a soil pressure of 25 Tont/m². The three towers were built on three rafts of size 31m x 40m., 31m x 37m., and 25m x 40m, and the building has performed satisfactorily.

Specifications for site investigation insist that when rock is encountered during drilling, the drill hole should be extended to about 3m in rock to ensure that what is encountered is bedrock and not a boulder. However, the soil drilling firms in Sri Lanka are reluctant to do drilling in rock as many of them do not possess the equipment and expertise for rock drilling. Hence these firms do not seem to give proper advice to their clients. There are instances where piles had been rested on boulders instead of bedrock, and remedial measures had to be taken to arrest the settlement of such piles.

Contract Conditions and Site Investigation

The construction of a Power House and Tailrace was undertaken by the Ceylon Electricity Board as part of a major Project. Both the consultant and the contractor for this project were foreign firms. During the excavation of the ground for the construction of the Power House and Tailrace, a large mass of earth had slipped into the excavation site necessitating the removal of an additional quantity of about 119,000 cubic meters of earth. The original estimated excavation was 196,000 cubic meters. The contractor claimed for payment for the additional excavation under a Changed Conditions clause, which the contractor had pressed for conclusion in the Contract Agreement at the negotiation stage. A Technical Committee consisting of representatives from the government, the contractor and the consultant examined this clause and agreed to include this in the Contract Agreement. The clause states :-

"Changed Conditions"

"The contractor shall promptly, and before such conditions are disturbed, notify the Engineer in writing of: (1) Sub-surface or latent physical conditions at the site differing materially from those indicated in this contract, or (2) Unknown physical conditions at the site of an unusual nature, differing materially from those ordinarily encountered and generally recognized as inherent in work of the character provided for in this contract.

The Engineer shall promptly investigate the conditions, and if he finds that such conditions do so materially differ and cause an increase in the cost of, or the time required for performance of this contract an equitable adjustment shall be made by the Engineer in writing accordingly. Any claim of the contractor for adjustment hereunder shall not be allowed unless he has given notice as above required; provided that the Engineer, may if he determines the facts so justify, consider and adjust any such claim asserted before the date of final settlement of the contract."

The Government of Sri Lanka appointed a four-man committee, which included the first author as a member, to investigate and report on certain aspects of the work

at the Power House and Tailrace site and the performance of the consultant, contractor and the Ceylon Electricity Board in this work.

It was evident from the investigations that the foreign consultant and the contractor had not appreciated the nature and behavior of the overburden in the Power House and Tailrace site area. The site was examined by a Foreign consultant geologist whose report, forms part of the contract document. It was stated in this report that slopes of excavation of 9m lifts will stand steeply and securely with berms, while the soil present at the site was different. The contractor, without realizing the nature of the material present at the site, went ahead with the excavation using shovel and front end loaders instead of using drag lines and buckets, causing cracks and slips on the slopes. Further, inadequate provision of surface drainage along the slopes by the contractor contributed to the earth slips.

The inquiry carried out by the committee showed that the site had not been adequately investigated before the side slopes of the excavations for Power House and Tailrace were designed. The overburden in the site includes soft deposits of alluvial and colluvial soils comprising river gravels and ill-sorted debris, mixed with clay and boulders. Attempts were not made to study the engineering behavior of these deposits in sufficient detail during initial site investigation.

According to the Engineering Agreement, it was the responsibility of the consultant to satisfy himself of the correctness and adequacy of the existing data and to obtain such additional data as he considered necessary. The only available drill hole on the section of the Power House excavation where slips occurred showed a very deep overburden extending down to 29m with patches of highly weathered gneisses. This hole caved in at a depth of about 21m. Therefore since this data indicated suspect conditions of stability, the consultant should have extended the site investigations by drilling additional holes in this area. Furthermore, it was observed that although near the surface signs of a highly unstable clay seam had been noticed, no bore holes had been drilled along the longitudinal section of the tailrace extending sufficiently far down to reveal the nature and extent of the overburden.

The committee of inquiry also found that the instructions given by the consultant to the contractor were lacking in detail and precision. Instructions issued by the consultant, which the contractor felt he could agree to, had been carried out promptly. However, whenever there was a difference of opinion between the contractor and the consultant, specially on the subject of drainage, such instructions had not been carried out promptly.

Though this project comprised 75% civil engineering work and 25% electrical and mechanical installations, the Ceylon Electricity Board had entrusted the major civil engineering works of the project to Electrical Engineers. Only works of a relatively minor nature, such as accommodation, roads, acquisition of sites, surveys and requisitions were entrusted to the Civil Engineering Branch. This resulted in an unsatisfactory situation where the Ceylon Electricity Board had to depend totally on the advice of the consultant without such advice being processed through competent local counterparts. The sole representative of the government in the execution of the contract had been interpreted to be the consultant.

Engineering projects of this nature involve many disciplines including geological, soils, structural,

electrical, mechanical and hydraulic engineering. The committee of inquiry recommended that an Advisory Board consisting of expertise from different Government Departments, State Corporations, and Universities should be set up to assist the government in monitoring such projects.

Foreign Consultants

Though sufficient expertise is available in Sri Lanka for site investigation work and laboratory testing, often aid or loan granting foreign agencies insist on getting foreign consultants to do this work. This has led to unnecessary drainage on the quantum of foreign aid and sometimes to technical problems as the foreign consultants are not fully familiar with the local ground conditions.

The Urea Fertilizer Factory at Sapugaskanda was designed and constructed with foreign assistance.

The main consultant for the project was a foreign firm, appointed by the aid giving agency, which wanted to get the site investigation and foundation report done by a foreign geotechnical firm. But the Board of Directors of the State Fertilizer Manufacturing Corporation, who were the clients, insisted that site investigation work should be done by Sri Lankan organizations as facilities were locally available. They proposed that the field work would be carried out using the resources of the Irrigation Department, Highways Department and Geological Survey Department, and laboratory testing and preparation of the report to be carried out in the Faculty of Engineering at the University of Peradeniya under the guidance of the first author. Representatives from the Foreign Consultant inspected the resources and expertise available in Sri Lanka for this work. They stated that though equipment and expertise available in Sri Lanka were sufficient to undertake the job, the Sri Lankans had no previous experience in carrying out foundation investigation for a Urea Factory. On the insistence of the Board of Directors of the State Fertilizer Manufacturing Corporation, it was finally agreed that the work would be done jointly by Sri Lankans and a foreign soil consultancy firm. Field work was carried out by the Departments of Irrigation, Highways and Geological Surveys under joint supervision by the foreign Soil Consultant - Dames and Moore, and the laboratory testing and preparation of the report was carried out in the Faculty of Engineering, University of Peradeniya, jointly by the first author and an engineer from Dames and Moore.

Because of the stand taken by the Board of Directors of the State Fertilizer Manufacturing Corporation, the resource and expertise available locally were utilized to do the job and this gave confidence to the Sri Lankans to undertake similar projects in the future. The main consultant was very satisfied with the performance of the Sri Lankans. When the site had to be preloaded with earth to control settlements under the different structures to be constructed, the preloading and monitoring of the settlements under preload were carried out by local contractors under the supervision of the first author.

Consultant's Responsibility

In Sri Lanka, there does not seem to be an easy way to compensate the client if the consultant makes a mistake, except to black list the consultant for future work by the client.

For a laboratory building in the Faculty of Engineering at the University of Peradeniya, a water-proof basement to store expensive measuring equipment was designed by a consultant engaged by the University. The ground water table at this site was well below the level of the basement floor. The basement was constructed by the contractor as specified by the consultant. After heavy rains, water had entered the basement and inspection showed that the basement concrete had cracked and water had entered through these cracks. On checking the design of the basement floor, it was found that the steel reinforcement provided at the top of the floor could only cater to the soil pressure acting at the bottom of the basement floor. The consultant had not allowed for the possibility of the floor slab being subjected to an upthrust due to water pressure during rains. In this case, the consultant was guilty of not taking this factor into account in the design, but the University could not recover the cost of repairs to the basement floor from the consultant.

WORK TO BE DONE

The authors believe that in order to improve the present geotechnical engineering practices in Sri Lanka, it is necessary to give adequate attention to the following areas :

- Code of Practice
- Conditions of Contract
- Project Brief
- Data Base
- Joint venture with foreign firms

Code of Practice

As stated in section 2.2 herein, the Code of Practice is a long felt need in the industry. Presently, the Institute for Construction Training and Development (ICTAD), Sri Lanka, with the assistance of selected experts in the field, is preparing the Code of Practice for Site Investigation for Foundations. It is expected that the work on this Codes of Practice will be completed within a year.

Some of the important areas which the Code of Practice should incorporate are :

- Site investigation levels required
- Protection to existing structures
- Appreciation of engineering behavior of local soils
- Requirements for adequate supervision and quality control during foundation construction
- A minimum professional fee structure for geotechnical work
- A mandatory requirement of appropriate professional inputs during design and construction

Conditions of Contract

There is no standard agreement of Conditions of Contract used in the industry for geotechnical engineering work. The existing practice is, that the selected consultant will draft an agreement on an ad-hoc basis to which the client agrees and signs. When a number of agreements used in practice, were reviewed the most common observation was that there was no indemnity clause to protect the client if there is any damage due to professional negligence or unforeseen conditions. In this situation the only remedy available to the client is litigation. But definitely it is a costly and time consuming activity.

Therefore, it is necessary to have a General Conditions of Contract appropriate for local situation clearly defining the obligations and duties of both parties i.e., client and consultant. In line with these General Conditions, it is necessary to have special conditions where necessary amendments can be made to suit specific situations.

Project Brief

The project brief is a document which should be prepared and agreed before the work is commenced for any project. It provides a set of datum in terms of the client's requirements and limitations of the project which are the guidelines for the rest of this project.

It is the duty of the professional advisers to utilize their professional knowledge and experience to gather information and data relevant to the project so that the client can be informed of all possible options and then to prepare the project brief accordingly at the inception of the project.

Data Base

It is very essential that the designers should develop and maintain data bases relating to the projects they get involved in for future reference. Especially in foundation engineering, maintenance of local data bases become very valuable information in future design and construction work. This should include but not be limited to the following :

- Site investigation data
- Assumptions made
- Design parameters used
- Performance data (settlements, cracks etc.)
- Cost data
- Methods, material and plant equipment used in construction

Joint Ventures with Foreign Firms

In order to develop local consultancy and contracting practices, it is mandatory wherever possible to award contracts to local professionals/firms.

Engagement of foreign consultants/contractors may be required due to the following reasons :

- a) Lack of local expertise in the area concerned.
- b) Donor Agency may enforce terms and conditions so that services of foreign firms are essential.

Because of the above reasons, if the services of foreign consultants/contractors are required, they should be instructed to form joint ventures with local counterparts.

The terms and conditions of the agreements between the government and the foreign organizations should clearly state the manner in which the technological transfer is to be done during the project execution.

REFERENCES

1. Report of the Committee appointed to investigate into the Earth Slips at Polpitiya Power House Site-Maskeliya Oya Project, Stage I, Contract No.1; (1968).
2. Site Investigation Report for Urea Fertilizer Factory at Sapugaskanda, (1976).