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Geologic Considerations in Civil Constructions - Malaysian Case Studies

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SYNOPSIS The need for adequate geologic input into civil engineering projects is common knowledge to all. However, quite surprisingly, in many construction projects in Malaysia geologic input is either totally lacking or highly inadequate. An indicator of the extent of neglect of geologic input into civil constructions in Malaysia is the fact that many soil investigation reports for these projects in this country do not contain a section on geology which has been publicised. This paper presents several case studies of civil engineering projects where geologic factors have been overlooked, thus resulting in the delay in the completion of the project and increase in the final project cost. The examples given include a bridge project, dams, building foundations, piling works and the search for construction materials for the extension of an airport.

INTRODUCTION

All civil works involving excavations and constructions for the various types of civil engineering structures must invariably deal with soils and rocks. Hence, it follows naturally that a thorough understanding of the geology of the construction site and its vicinities is essential, if not vital, to the successful completion of the project. This is common knowledge to all, and geologic site investigation is included in engineering studies of proposed schemes pretty much as a standard practice in the well developed countries. However, it is rather surprising that in Malaysia, a country which is rapidly turning from a developing to a developed country, many construction projects were and continue to be implemented with little or a total disregard for the site geology. An indicator of the extent of neglect of geologic input into civil constructions in Malaysia is the disturbing fact that many soil or site investigation reports for engineering projects in this country do not contain a section or even a brief write-up on the site geology. The inclusion of a geological report comprising the basic geologic map and stratigraphical cross-sections of the soil and rock strata appears not to be a compulsory requirement. It is only requested on an occasional basis at the discretion of the project engineers, unfortunately often at a late stage when problems have already begun to surface.

This paper presents several case studies of civil engineering projects where geologic factors have been overlooked in the initial site investigation stage, only to be picked up again at a much later stage when serious problems have begun to develop. The consequences that followed include the delay in the completion of the project, remedial works, etc. accompanied by drastic increase in the project costs. Cases are also given where geologic factors or adversities have been recognised at an early stage and appropriate measures were then taken in the design and construction of the structures to suit the site geology, thus ensuring greater success in completing the projects.

CASE STUDIES

The examples given in this paper include building foundations, piling works, excavations at dam sites and quarries, a bridge project, construction materials for the extension of the runway for an airport and a highway cave-in. Many other cases can also be cited, but for illustration purpose the examples presented below should be sufficient to cause concern for the civil construction industry to perhaps demand for more adequate geologic inputs or studies in future construction projects in Malaysia.

CASE STUDY A - Building Foundations on Limestone

It is perhaps most appropriate to begin with case studies on building foundations on limestone. Many buildings tens of storeys high are currently being built on limestone in the Kuala Lumpur metropolis (and other urban centres such as Ipoh), and it is only recently that the geologic intricacies of limestone terrains (such as solution channels, cavities, overhangs, arches, thin slabs, floaters and the highly pinnacled bedrock profile) and the problems they pose to the foundation engineers have been recognised and reckoned with by some foundation engineers. What started it off was the experience of one of the first case studies of foundation in Malaysia in Kuala Lumpur which has been much publicised in 1979/80. In that particular case, what began as a simple soil investigation consisting of less than ten boreholes (without the involvement of a geologist) for a proposed highrise building ended up with about three hundred boreholes (plus the engagement of a geologist) as the true nature and intricate patterns of the solution features began to unfold itself. The great variability and unpredictability of the various solution features made it necessary to drill at times at spacings as close as 1-2m in certain parts of the building site, and introduced many problems in the construction of the foundations, with the result that the project was delayed for several years.

Since the case study mentioned above, many other tall building projects in Kuala Lumpur have also encountered similar ground conditions in limestone bedrock. An adequate number of deep borings and probings are now often requested to enable one to construct more accurately the nature and extent of the various karst features, occasionally with the help of a geologist.

In another case that is currently under construction, the ground conditions as revealed by detailed soil investigations (including geological report) show variable cavernous and massive grounds on different quadrants of the building site. As opposed to the original plan, the components of the building were then shifted around so as to suit the site geology. For example, it was decided to found the tower block on the massive limestone, and the lower and lighter structures on the cavernous portion.
Fig. 2: H-piles in Kenny Hill formation soils/rocks, showing poor penetration and pile damage.

The recognition and proper understanding of the geologic nature of the Kenny Hill formation rocks can be put into advantage as by some piling contractors where the method of piling (such as driven versus bored piles, sheet piles versus diaphragm walls, etc) can be selected to suit the nature of the ground. Not only would the difficulties of pile penetration be eliminated, in certain cases the use of the appropriate construction method to suit the ground has enabled the piling contractors to complete jobs ahead of schedule and to walk away with handsome profits.

CASE STUDY C - Granite Boulders or Corestones in Relation to Earthworks Excavations

A large part of Peninsular Malaysia is underlain by granitic rocks, much of which are overlain by a thick mantle of residual soils, the result of intense tropical weathering. Embedded in the residual soils are frequent occurrence of granite boulders or corestones, some of which are several metres in length. In soil investigation, the granite corestones pose problems as they can be mistaken for bedrock. They are also often missed when occurring between two boreholes. For purposes of earthwork excavations, such as for dams, housing development, quarries, they not only cause difficulties in excavations but also can cause drastic deviations in the quantities of earth versus rock materials estimated from borehole results.

In the Kenyir Dam site in Trengganu, for example, the particular abundance of these granite boulders in the residual soils was not recognised in the soil investigation stage. Soil profiles based on interpolation between boreholes show strata of soils only, with little or no boulders, and the contractor made his bid accordingly. Difficulties with the boulders were experienced only during excavations for the saddle dams (see Fig. 3), with the result that additional claims for compensation were made by the contractor to
Similarly, the relative abundance of corestones often dictate the feasibility of opening up a new quarry (for rock) or starting a borrow pit for earthfill materials in a granite terrain. On one hand the abundance of corestones (which have been mistaken for bedrock during drilling) reduce the amount of sound rock that can possibly be extracted from a quarry; and on the other hand it reduces also the amount of soil materials available from a proposed borrow pit.

CASE STUDY D - A Bridge Project

This case study illustrates the total lack or disregard for geologic input or considerations in the construction of a particular bridge. The contractor was provided with a typical soil investigation report complete with the various soil layers at the bridge site, albeit minus the geology or details on the bedrock. On commencement of driving H-piles it turned out that these piles were disappearing into the cavities of the underlying cavernous limestone bedrock. Neither the soil drillers nor the piling contractor claim any previous knowledge of the existence of limestone, since geologic factors were never considered in the first place. The irony is that adjacent to the bridge site stood a large limestone hill, with its characteristic precipitous cliff face which even an engineer can easily recognize. Moreover, some short distance away from the bridge site is a good exposure of banded skarn rocks (a contact metamorphic rock indicative of limestone-granite contacts). The project was carried out without any geologic input by a geologist who would have forewarned of the presence of limestone at the bridge site and hence its possible associated problems in the bridge construction. The contractor lost several million dollars since he had not anticipated the difficulties associated with the presence of the limestone. Fig. 4 shows the bridge in question.

CASE STUDY E - Extension of an Airport

In the extension of the runway for an airport located on the coastal alluvium, excavations have been made to strip away the surficial peaty or organic clay layers along the runway extensions, and materials were needed to backfill these pits. Unfortunately, the contractor had earlier proposed using the beach sand deposits nearby and had thus tendered for the job accordingly. Obviously, the decision was made without due regards or prior considerations for the various dynamic geological processes (erosion, accretion, littoral drift, etc.) that the beach sand may be subject to. The effect of excavating beach sands, from the environmental view point, was not thought of earlier. As it turned out later, the problems of possible erosion and scouring at the coastline and the detrimental effects that these may cause to the beach made it not possible for the contractor to utilize the beach sand as proposed, at least not the quantity that is required for the purpose. Since then, the project has been delayed considerably. Additional problems were faced since the open pits were subject to flooding during the wet seasons due to inavailability of cover materials. Further inland, fill materials of suitable quality were available, though at slightly higher cost. Unfortunately, they have not been considered earlier during the tender stage.

CASE STUDY F - Highway Cave-in

Recently, a cave-in occurred along one of the major highways in the country, see Fig. 5. It caused quite a stir in the public, especially when it was revealed in the local press that the entire highway was constructed without the involvement of the Geological Survey Department. Soil investigations that followed the cave-in revealed that the particular stretch affected was underlain by, among other
things, limestone. The contention of the Geological Survey Department was that if consulted, they could have at least indicated or foretold of the occurrence of limestone lenses nearby the cave-in site. Apparently, the stretch of highway had sunk into collapsing sinkhole in the limestone bedrock, an occurrence which has also been reported in other parts of the country. As a result of the cave-in, the highway was partially closed to enable investigation work to be carried out, and a temporary diversion road had to be built rapidly. It also spurred the authorities into carrying out various site investigation studies all along the completed highway, to check the stability of the ground.

It is clear from this example that the highway was built not only without involving the Geological Survey, but perhaps worse than that, without the use of available geologic maps. The use of geologic maps, and preferably with the help of a geologist, would facilitate the proper selection of highway route and where necessary indicate positions that can pose potential problems which would hence require more detailed studies (deep borings, etc.) prior to construction, or perhaps re-routing.

CONCLUSIONS

This paper presents some examples of engineering case studies where inadequate or the lack of geologic inputs, particularly at the early site investigation phase of the project, have resulted in later construction problems, medial works, delays or even failures. Various types of engineering projects are included, covering different geologic terrains or rock formations.

It would appear that a primary common cause of these failures is the fact that many engineers in this country do not seem to even think of acquiring geologic inputs in the first place. To many engineers here geology does not appear to be relevant, let alone necessary. The reluctance of the civil construction industry here to include geologic studies in their projects may be attributed to several reasons, some of which are listed below:

- civil engineers here fight shy of geology since the majority do not have a good grounding in geology during their university education. This is in part due to the failures in the teaching of geology to civil engineers by instructors having little knowledge or experience in engineering, thus the relevance or connection between geology and civil engineering is not shown.

- the clients, consultants, contractors or drillers generally are not prepared to include a section on geology since they would then have to pay for the service of a geologist. The tendency is to get-by without having to engage a geologist.

- government departments such as the Public Works Department, Drainage and Irrigation Department, etc., civil consultants and major contractors in general do not employ in-house geologist since they feel that this is not justifiable. The wisdom of this attitude is perhaps questionable, the employment of engineering geologists well versed in soils and foundations (besides rock mechanics, etc.) is definitely not out of place - as evidenced by examples in the developed countries.

- the Geological Survey Department contains a small section on engineering Geology staffed by 4-5 geologists. Its role in the civil construction scene has been minimal, at most, since its service is only called for on an ad-hoc or occasional basis.

In all fairness, it must be added here that some progress of groups of engineers here do engage geologists on job basis. This healthy trend is picking up, albeit slowly, perhaps due in part to the greater awareness or lessons taught by several past failures, some of which have become cases for litigation.

Finally, a quote from Karl Terzaghi, the Father of Soil Mechanics who also wrote much on geology/engineering geolc would seem appropriate here: "Examining the array of useful knowledge which has filtered into my own system and crystallized into sound judgement, I find that it contains one ounce of geology for every pound of theory of structures and soil mechanics. The one ounce of geology is as essential as the yeast in the process of fermentation ------" (Terzaghi, 1957).

True to these great words of K. Terzaghi, the Malaysian civil engineering scene seems to be lacking and badly in need of that little ounce of geology that at times was crucial to the success of the project.

REFERENCE