Saving on the Geotechnical Investigation – A False Economy

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ABSTRACT

For an infrastructure project in Sydney south-west, the client organised a geotechnical investigation via his structural engineer for the design and construction of the facility. The geotechnical investigation comprised nine bores augered to the top of rock and the report made recommendations for foundations. The tender design, based on the recommendations of the geotechnical investigation, resulted in piled foundations of varying sizes and depths. Some of the piles were designed as 900 mm diameter with 5.5 m sockets into rock. Following the award of the contract for the piling works, the piling contractor arranged for core drilling of the rock and redesigned the piles based on significantly higher design parameters. This case study compares the cost of the piling works based on the original geotechnical investigation with the cost of redesigned piling works. It emphasises the cost savings made during the initial geotechnical investigation can lead to more expensive designs and loss of initial cost savings many times over during construction.

Keywords: investigation costs, piling costs

1 INTRODUCTION

An infrastructure project was proposed in south-western Sydney and the client via his structural engineer organised a combined geotechnical and environmental investigation. The client directly commissioned the investigation. The geotechnical report states that the objective of the investigation was to assess the subsurface ground conditions and provide comments on several items including "suitable footing type including allowable bearing capacity".

This is a real site and the numbers presented in the paper are also real, however, the location and names of the some parties have been withheld.

2 INITIAL GEOTECHNICAL INVESTIGATION

The combined geotechnical and contamination investigation for the site was carried out by a company specialising in geotechnical and environmental investigations. For the investigation, a total of nine (9) boreholes were drilled across the site and were spaced to provide reasonable coverage of the structure envelope. The bores were reported as being drilled using spiral augers attached to a V-bit to refusal depth on shale followed by tungsten carbide (TC) bit drilling into shale to refusal depths ranging from 5 m to 8 m. No coring of the rock was undertaken. A total length of drilling was 55.4 m. The strength of the shale was subjectively assessed by visually examining the shale cuttings off the augers and observing the TC bit resistance.

The subsurface profile given in the geotechnical report was summarised as topsoil over filling, silty clay and bedrock. The bedrock was encountered at depths ranging from 4.4 m to 7.4 m and visually assessed to be medium strength, extremely to distinctly weathered shale which increased to medium to high strength with depth.

The geotechnical investigation report recommended that footings for the structure be piers founded on weathered shale bedrock adopting an allowable end bearing pressure of 600 kPa. A shaft adhesion of 20 kPa was provided for the sections of the piers below 1 m depth.

It is estimated that the cost of the above geotechnical investigation component with some laboratory and geotechnical reporting would have been of the order of $10 000 plus GST.

3 INITIAL DESIGN

The structural engineer for the project adopted the findings and recommendations of the geotechnical report and designed the footings. The initial pile design was for 392 bored piles founded in rock. The pile designs ranged from 450 mm to 1050 mm in diameter and from 3.0 m to 9.4 m in depth.

Details of pile diameters and depths for the initial design are given in *Table 2*.

The initial foundation design quantities were:

Linear metres of piles	1754 m
Quantity of concrete	845 m^3
Reinforcement	51.5 tonnes

It was the above foundation design which went out to tender for construction. The quantities of concrete and steel had an allowance for wastage and spoil.

4 ADDITIONAL INVESTIGATION

Following the award of the piling works tender, the Piling Contractor, SFL/Piletech, engaged Douglas Partners to reassess the underlying rock strength by coring the rock. Four (4) boreholes were drilled on the site by augering and wash boring to top of rock and recovering approximately 3 m of NMLC size (52 mm diameter) cores of rock.

The additional investigation was suggested by the piling contractor, not the client or his structural engineer.

The recovered cores were logged describing the rock type, strength, weathering, bedding planes, jointing and defects. The rock strength was assessed using Point Load Index Strength test and the results ranged from 0.2 MPa to 5.1 MPa with an average of 2.7 MPa. As the defects were visible and the rock could be tested for strength, it was possible to classify the rock using the Pells et al (1978, 1998) rock classes.

The subsurface profile encountered in the bores was clay over siltstone or sandstone. (It is noted that the site had been stripped of topsoil and filling prior to the additional investigation.) Extremely low to very low strength sandstone (Class V) was found at depths ranging from 3.2 m to 4.6 m with medium to high strength sandstone (Class III) encountered at depth of 4.9 m to 6.0 m depth.

There was a different in rock description as the additional investigation described the rock as siltstone or sandstone while the previous investigation described the rock as shale. It may be that the grinding of the rock using a TC bit in the initial investigation did not allow for a proper identification of the rock.

A summary of the rock depths from the additional investigation is given in *Table 1*.

Table 1: Borehole summary

Stratum	Depth to Stratum
Extremely low to very low strength sandstone (Class V)	3.2 m - 4.6 m
Low strength sandstone (Class IV)	4.5 m - 5.3 m
Medium or high strength sandstone (Class III)	4.9 m – 6.0 m

As a result of the additional investigation, serviceability end bearing pressures of 1 000 kPa, 2 000 kPa and 6 000 kPa were suggested for Class V, Class IV and Class III sandstone respectively.

Using the same quantities of work as for the initial investigation but including an allowance for rock coring in each bore, the cost of the field work, laboratory testing and reporting is estimated to be of the order of $15 000.

5 REVISED PILE DESIGN

As a result of the additional investigation, the Piling Contractor was able to redesign the piles with higher end bearing pressures and shaft adhesion. The redesign resulted in the same number of piles but with 121 piles of 600 mm diameter and 271 piles of 400 mm diameter. The revised pile design is given in *Table 2*.

Table 2: Revised Pile Design

Pile Type	No of Piles	Initial Design		Revised Design	
		Pile Diameter (mm)	Length of pile (m)	Pile Diameter (mm)	Length of pile (m)
A	84	1050	3.0	600	3.4
B	29	900	3.0	600	3.4
C	29	600	3.0	400	3.4
D	15	750	6.7	400	5.2
E	63	750	5.5	400	4.9
F	15	600	6.0	400	5.2
G	32	600	5.1	400	4.9
H	27	450	6.0	400	4.9
I	6	750	8.9	600	5.3
J	2	750	9.4	600	5.3
K	38	450	3.5	400	3.0
L	52	600	5.0	400	5.3

6 COMPARISON OF PILE DESIGNS

The revised pile design generally reduced the pile diameters and, in many cases, decreased the pile depths. The most noticeable changes were Pile A which was reduced from 1050 mm diameter to 600 mm diameter and Pile J whose depth decreased from 9.4 m to 5.3 m. There were some significant changes. A summary of the quantities involved in both the initial and revised design is provided in *Table 3*.

Table 3: Pile Design Comparison

Quantities	Initial Design	Revised Design	Savings	
			Quantity	Percentage
No of piles	392	392	0	0
Linear length of piles	1754 m	1668 m	86 m	5%
Concrete Volume	845 m^3	306 m^3	539 m^3	64%
Reinforcement	51.5 tonnes	22.7 tonnes	28.8 tonnes	56%
No of days piling	47 days	19 days	28 days	60%
Amount of spoil	1440 tonnes	550 tonnes	890 tonnes	62%

The cost benefits of the redesign are provided in *Table 4*.

Table 4: Cost Benefits

	Initial Design	Revised Design	Savings	
			Quantity	Percentage
Approximate cost of investigation	$10 000	$15 000	($ 5000)	(50%)
Cost of piling	$620 000	$425 000	$195 000	31%

On this particular project, the client saved approximately $5 000 on the geotechnical investigation by not coring the underlying bedrock. Due to the conservative recommendations contained in the initial geotechnical report, the cost of the piling works as initially designed was $620 000. However, if the client had spent the extra money, approximately $5 000, to core the rock and obtain more appropriate design parameters, the pile design would have cost $425 000 and occupied 19 days in the program.

Therefore an initial saving of $5 000 on the geotechnical investigation cost the client approximately $200 000 more in the long run. In other works, the additional piling costs were nearly 40 times the initial cost savings made during the investigation.

The redesign also lead to other savings such as the reduced time of site, reduced interest payment on loans, reduced site administration costs, etc. This can be significant on some site, especially where there is a tight construction program and/or high liquidated damage costs. The major saving on this particular site was the reduced time spent on the site as there was a tight construction program.

There were some other costs involved in that the piles had to be redesigned by engineers following an additional investigation and there was a delay on site while the redesign was being carried out. These costs were significantly less than the savings.

7 COMMENTS

In this case, the initial geotechnical investigation was not able to properly assess the rock strength and defects within the bedrock because no coring of the rock was undertaken. Therefore it was not possible to assign rock classes to the bedrock. The cored bores, although more expensive to drill, provides a better assessment of the rock strength and allows for viewing the defects of the "in situ" rock. Once this information is obtained, it is possible to assign rock classes to the bedrock using the Pells et al method and provide more appropriate design parameters.

The initial design had a number of piles founded at depths greater than the depth of the initial investigation It would have been assumed that, based on the initial investigation, the sockets would be in medium to high strength rock although the design of the piles was based on design parameters appropriate for extremely low strength rock. The additional investigation established that the initial design would involve drilling sockets into high strength sandstone. This would have resulted in slower drilling rates, more time on site and a possible variation claim for different ground conditions to that reported in the initial investigation.

The original investigation was commissioned by the end client. In arriving at a decision, the client should be aware of the other factors such as long term cost implications, timing, availability, etc rather than just comparing prices. If in doubt, the client should ask his structural or civil engineers for advice and not be driven by price alone. In most things, you get what you pay for. A "limited" geotechnical investigation will generally provide "limited" advice or recommendations.

In most cases, a client will not realise the long term implications of his "initial" cost savings because he has nothing to compare it. He only has the recommendations of the one investigation and does not have the luxury of another, possibly dearer, investigation to compare other possible recommendations.

It raises the dilemma of how much do geotechnical engineers reduce the price (and consequently the scope of works) of geotechnical investigation to win a proposal knowing that it will probably cost the client more in the long run. In such cases, a geotechnical engineer should explain its limitations in the proposal.

If a client is totally price driven, he should be comparing "apples" with "apples" and provide a detailed schedule of rates rather than asking for a price for a geotechnical investigation.

8 CONCLUSION

It was only the astuteness of the piling contractor in this case which provided a cost saving of a significant amount of money. How the saving is distributed is another question and not discussed in this paper.

The above example shows the "savings" in investigation costs of approximately $5 000 nearly lead to costly foundation solutions, some $200 000 more expensive than necessary. Often, many clients are mislead in thinking that they are saving money, but as they do not carry out the comparison, they are unaware of the potential cost saving which can be made in the long run.

In addition to the actual cost of piling, there are also other factors such as site costs and construction program which can be adversely affected by "savings" made during the geotechnical investigation stage.

Each project is different and therefore the quantities will vary, but the principle is the same. However, it can be said that savings on many medium to large sized geotechnical investigations is often a false economy.

The above case reconfirms the conclusion of Phillips et al (1990), “Competent geotechnical input can provide significant cost savings during the course of a project, both at the feasibility and design stage, and during construction. The preparation of reliable and comprehensive site information will increase contractor confidence and reduce the risk of construction costs."

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