Some Thoughts on Bridging Research and Practice in Geotechnical Engineering

Victor Li
Victor Li & Associates Ltd.

doi: https://doi.org/10.21467/proceedings.8.2.1

ABSTRACT

The behaviours of soils are too complex to be modelled without simplifying assumptions. Despite the limitations, there are still many useful albeit approximate geotechnical theories that can be relied upon to assist engineers in developing innovative schemes for design and to guide them in making rational decision for solving problems on site. The importance of the construction effects cannot be overemphasized when trying to understand or predict geotechnical behaviours. The paper discusses the nature and value of geotechnical theory, the state-of-play of design practices and make suggestions on bridging theory and practice. Examples are presented to illustrate how knowledge in theory can be used to improve the design practice and vice versa.

1 INTRODUCTION

Young graduates who are fresh out of universities may be deeply impressed by powerful computer software available for analyzing almost everything in geotechnical engineering. After running geotechnical programs day in and day out for a few years in their training, they may build up confidence on geotechnical analysis, believing that actual geotechnical structures should and will behave as predicted by computer analyses. This is far from being true in reality. Engineers seldom realize that the method of construction can have a huge impact on the behaviours of a geotechnical structure. If the analyses fail to replicate the correct procedures of construction, the prediction can be wrong by a big margin.

Geotechnical engineering, like many other branches of civil engineering, is often experienced-based. The design rules and practices established based on past experiences are seldom challenged. But the harsh fact is that prevailing design rules and practices are in many instances expedient guidelines without a sound technical basis.

This paper presents some observations on why geotechnical theories can be so wide of the mark and give examples of how some of the prevailing design practice can lead to nonsensical outcomes. Some suggestions for narrowing the gap between theory and practice will also be presented.

2 NATURE OF GEOTECHNICAL THEORY

Soils and rocks are non-homogeneous materials with high innate variability in field. Geomaterials are generally three-phase materials comprising air, water and solid. Their behaviors are complex, often time-dependent, influenced by pore-air pressure and pore-water pressure, and dependent on stress history, stress/strain path and stress level. Naturally, the behaviours of a geotechnical structure supported by geomaterials are equally complex and affected by factors such as construction method and equipment used for construction. The complex behaviours of geomaterials lead to the following characteristics of geotechnical theories:

- Significant simplifications or idealization are needed to make geotechnical theories simple and manageable for routine design.
- Theories which fail to capture the influence of construction method on geotechnical behaviours are often highly misleading and harmful.
- Predictions are often poor due to variability of soil properties, inaccuracy of theory and difficulties in obtaining representative input parameters for analysis.

© 2026 Copyright held by the author(s). Published by AIJR Publisher in " Proceedings of The HKIE Geotechnical Division 46th Annual Seminar 2026: Bridging Theory and Practice in Geotechnical Engineering" (GDAS2026). Organized by the Geotechnical Division, The Hong Kong Institution of Engineers, Hong Kong on May 12, 2026.

Proceedings DOI: 10.21467/proceedings.8.2; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-688301-1-0

2.1 Limitation of geotechnical theory

The classical theory of consolidation developed by Terzaghi (1925, 1943) is a good example to illustrate the simplification used in a geotechnical theory. The coefficient of consolidation c_v, defined as $k/(\gamma_w m_v)$ where k and m_v = the permeability and coefficient of compressibility of soil respectively and γ_w = unit weight of water, is assumed to be constant in the governing differential equation. With this assumption, an analytical solution can be obtained for the relationship between the degree of consolidation and the time factor. Although k and m_v both decrease with void ratio, they do not diminish in a linearly proportional manner. c_v is therefore not constant and changes as consolidation progresses. c_v cannot be treated as a fundamental property of soils and its magnitude is expected to be scale-dependent. In simple terms, it is a fudge factor which forces agreement between theory and observed data. Strictly speaking, the value of c_v inferred from an oedometer test of a thin clay sample may not be representative of a clay layer much thicker than a test specimen.

In the wetting band theory developed by Lumb (1962), the governing differential equation for vertical infiltration flow of water into an unsaturated slope depends on the parameters k and diffusivity D defined by $k\frac{\partial U}{\partial w}$ where U = potential (or suction head) and w = volumetric water content of soil. By assuming D and k to be constant, an analytical solution can be obtained for predicting the rate of rain infiltration into the slope. In actuality, k and U are both non-linear functions of w. The accuracy of the wetting band theory hinges on whether good representative design parameters for D and k can be obtained by field measurements.

Because of the need for simplification and idealization, most if not all geotechnical theories are at best approximate theories.

2.2 Influence of construction

Geotechnical engineers including renowned researchers often fail to appreciate the influence of construction on the behaviours of geotechnical works.

In most textbooks on foundation, the shaft resistance τ of pile is predicted using the following deceptively simple equation.

$$\tau = \sigma_h \tan\delta = K\,\sigma_v \tan\delta = \beta\,\sigma_v \quad (1)$$

where δ = friction angle soil at the pile/soil interface, σ_h and σ_v = horizontal and vertical stress respectively, K = coefficient of horizontal pressure and β = shaft friction coefficient. Eq.1 involves a series of simplifications. Textbook authors often mislead readers into misbelieving that there is a sound soil mechanics basis for Eq.1. In fact, none of the quantities in Eq.1 can be known with certainty except perhaps for σ_v. The horizontal stress σ_h and the friction angle δ depends significantly on the construction method and do not necessarily relate to the soils in the original soil profile.

When the temporary steel casing is used for construction of a bored pile, the soils outside casing will be subjected to different modes of shear movement depending on whether a vibrator, an oscillator or a rotator is used for installing the casing (Li 2026). The soils outside the casing will also be densified to a differing degree depending on the equipment used for sinking the casing and this will affect the magnitude of both σ_h and δ.

If a permanent liner is provided for a bored pile, there will be an annular gap between the liner and the temporary steel casing (Li 2026). When the casing is extracted, the soils outside the casing will displace towards the liner. If the arching effect of soils is significant enough, the pile bore is stable and an open void will remain, giving $\sigma_h = 0$. Otherwise, the soils will continue to move and close up the gap. Figure 1 shows a photograph of a stable gap observed outside the permanent liner after extraction of temporary casing for a project in Yuen Long (Li 2026) and a graph for the measured depth of a similar stable deep annular void for another bored pile in a project at Tseung Kwan O (Lam & Li 2023). Note that the depth of stable void was deeper than 40m in the first day after extraction of temporary casing.

Proceedings DOI: 10.21467/proceedings.8.2
ISBN: 978-81-688301-1-0

Series: AIJR Proceedings
ISSN: 2582-3922

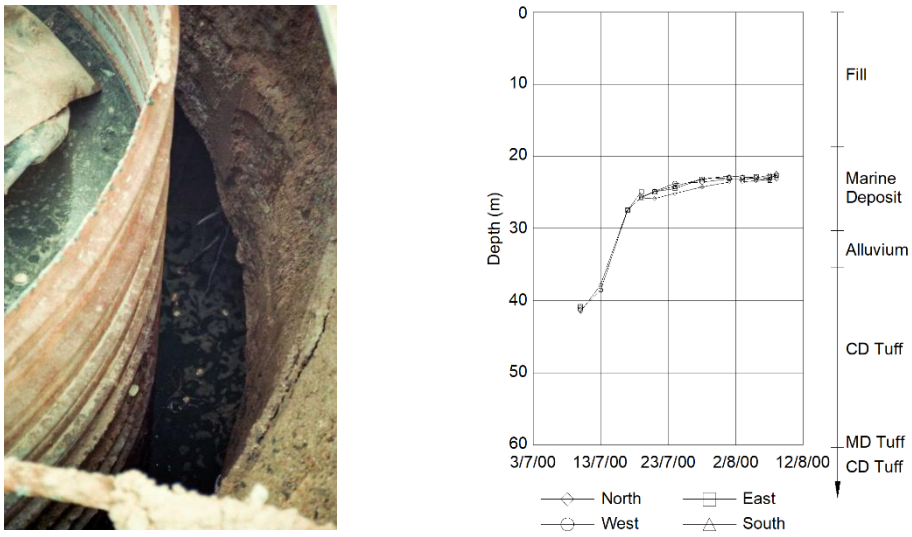


Figure 1: Annular void outside permanent liner (Li 2026; Lam & Li 2003)

If the arching effect is not sufficient to maintain a stable pile bore after extraction of casing, σ_h will drop from a higher value corresponding to its initial state to a smaller but non-zero value after closing the gap. According to the study by Lo et al. (2001), the final horizontal stress is small and well below the pressure under the at-rest condition.

When a permanent liner is provided, the interface friction angle δ may have no relationship to the soils located next to the bored pile in the original soil profile. If the annular void is stable after extraction of casing, the materials filling up the gap may come from soils sloughing off the stable pile bore from higher levels or fill materials placed by the contractor before constructing the pile cap. The interface friction angle δ also depends on the nature of the permanent liner. If a thin steel casing is used, δ may be smaller due to the smooth surface of the casing. If a spiral corrugated liner is used (see Figure 1), δ is expected to be higher due to the undulating surface of the liner.

If no permanent liner is used, the pile bore will be in direct contact with the tremie concrete. The horizontal stress σ_h along the pile bore will simply be the pressure of wet concrete. If one knows how to predict the pressure profile of wet concrete, he may obtain a better prediction of the shaft resistance than using soil mechanics theories.

The prediction of shaft friction of a driven H-pile is by no means a simpler task than that for a bored pile. The author recalls a technical talk delivered by a Rankine lecturer some years ago. The speaker presented the results of a study in which he had used an analysis model developed by his team to obtain accurate predictions of the behaviour of an H-pile. Like most engineers would have done, the soil layers used in his analysis model was based on the original soil profile inferred from boreholes. The Rankine lecturer failed to recognize the important phenomenon that when an H-pile is driven or jacked into the ground, the soils on both sides of the web of the pile will be dragged downwards. Vertical voids will be formed below the ground surface as shown in Figure 2. The soils in contact with the H-pile will be quite different from those inferred from the original soil profile. The vertical voids outside the H-piles are usually backfilled by contractor using whatever fill materials they can find on site after completion of pile installation. It is puzzling why a good prediction of pile response can be obtained by the Rankine lecture using the original soil profile without knowing the depth of voids and the materials used for backfilling the voids. Again, Eq.1 seems to be of little use in helping us to predict the shaft resistance of an H-pile.

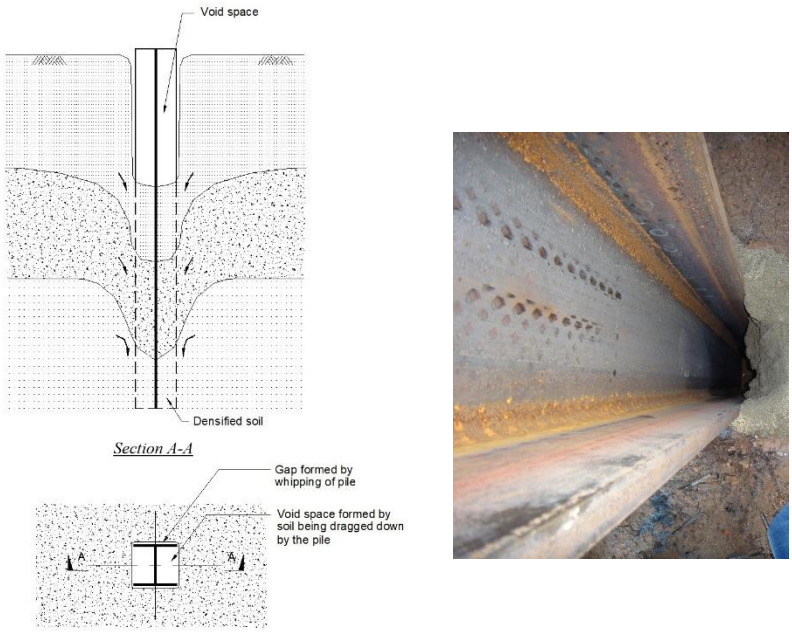


Figure 2: Voids formed during installation of H-pile (Li, 2026)

The influence of construction is equally important for assessing the pullout resistance of soil nails. Chu & Yin (2004) presented pullout test results of soil nails measured in the laboratory. The vertical pressure was applied after the test soil nail had been installed inside the test apparatus. Based on this test arrangement, Chu & Yin (2004) observed a linear relationship between pullout resistance and applied vertical pressure. In the discussion to their paper, the author argued that the test procedures adopted by Chu & Yin was inappropriate (Li & Lo 2007). The overburden pressure of an existing slope should be in existence before the soil nails are installed. After the drillhole for a soil nail has been formed, the arching effect of soil will be mobilized to resist the overburden pressure such that the radial stress acting at the surface of the drillhole must be zero if the drillhole is stable. The overburden pressure sensed by the soil nails is practically zero, not the initial existing overburden pressure. The pullout resistance of soil nails should be attributed to other factors not related to the overburden pressure of soils, such as normal stress induced by constrained dilatancy, interface dilatancy due to overbreaks in the drillhole and/or physical bonding between cement grout and soils. To obtain the real behaviour of soil nails, Li & Lo (2007) argue that the drillhole for test soil nail should be formed after the vertical pressure has been applied to the soils in the test apparatus. Such a test arrangement has indeed been adopted later by Su et al. (2008). The new results indicate that the pullout resistance of soil nails is now largely independent of overburden pressure.

2.3 Uncertainty of prediction

Geotechnical predictions are subject to large uncertainties due to inaccuracy caused the simplifying assumptions made in the theory, use of meaningless formulas, innate variability of soil properties/input parameters, failure to account for effect of construction or a combination of these factors. As remarked by Terzaghi (1963), '*in soil mechanics, the accuracy of computer results never exceeds that of a crude estimate*'. As a norm, it is unrealistic to expect a very good prediction to be obtained from a geotechnical theory.

Table 1 shows the shaft resistance coefficient β for different pile types and soil types inferred from instrumented test piles in Hong Kong (GEO 2006). The ranges of β are so wide that Eq.1 is of little practice use in assessing the shaft resistance of piles because shaft resistance is highly dependent on construction methods and many other factors.

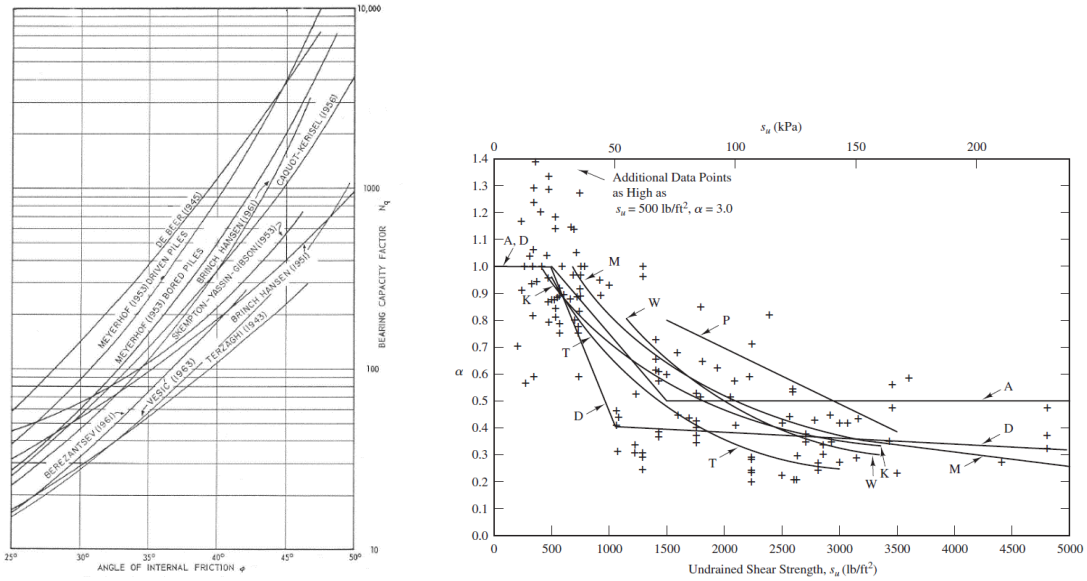
Proceedings DOI: 10.21467/proceedings.8.2
ISBN: 978-81-688301-1-0

Series: AIJR Proceedings
ISSN: 2582-3922

Table 1: Typical values of β (GEO 2006)

Type of piles	Type of soils	Shaft resistance coefficient β
Driven small displacement piles	Saprolite Loose to medium dense sand	0.1 – 0.4 0.4 – 0.5
Driven large displacement piles	Saprolite Loose to medium dense sand	0.8 – 1.2 0.2 – 1.5
Bored piles and barrettes	Saprolite Loose to medium dense sand	0.1 – 0.6 0.2 – 0.6
Shaft-grouted bored piles & barrettes	Saprolite	0.2 – 1.2

Figure 3(a) which shows the bearing capacity factor N_q for the toe resistance of a solid pile developed by various renowned researchers. The variations in N_q are large purely due to the differences in assumptions or simplifications used in different bearing capacity theories. Figure 3(b) presents the data and design lines marked with A, D, K, M, P, T and W recommended by various researchers for the adhesion factor used for assessing the shaft resistance of piles in clayey soils. Again, there are large differences amongst the various design lines likely to be due to innate variability of soil properties and dependence of α on construction methods.



(a) (b)

Figure 3: (a) Bearing capacity factor N_q for toe resistance of pile (after Vesic 1967) and (b) Adhesion factor α for clay (after Coduto et al. 2016)

3 DESIGN PRACTICE – THE STATE OF PLAY

3.1 From control to over-control

With the introduction of design codes, technical guidance notes, practice notes and design guidance documents promulgation by various government departments, geotechnical design has become increasingly codified and regulated in Hong Kong. Design rules and practices will emerge to deal with the restrictions arising from formal or de facto regulatory requirements. As discussed by Li (2026), such design rules and practices possess the following general characteristics.

a. They are simple and usually conservative.
b. Deemed-to-satisfy guidelines are specified to avoid dealing with the analysis and checking of otherwise more complicated actual situations.

c. Design rules or practices are often ad-hoc or expedient suggestions. They are not necessarily sound and can sometimes be nonsensical.
d. They are rigid requirements. There are penalties for not following the design rules, such as a longer period for obtaining approval, the need for trial pile and etc. Otherwise, design engineers will change the design rules frequently and design approval will no longer be a straight forward task for regulators.

Design rules and practices are created to make checking of design submissions easier and to prevent designers from being too aggressive in their designs. Geotechnical engineers who want to be innovative and have more freedom in design often find it frustrating when trying to deviate from established rules and practices. The author shared some of his frustrations in design submissions in Li & Lo (2008). The following are some more cases to be shared.

In Hong Kong, foundations are customarily designed as either footings or pile foundations. Also, computer programs need to be pre-approved by the Buildings Department before they can be used for engineering analysis for design submissions to the department. An internationally renowned professor and foundation expert has once told the author the following story. He was appointed as a consultant to develop a pile-raft design for a project in Hong Kong. Obviously, it would not be an easy task to secure the approval of such an 'innovative' design even though pile-raft foundations are not uncommon outside Hong Kong. The professor initially carried out the design using design charts and manual calculations. The design was rejected on the ground that a more rigourous analysis should be used to justify the design. He then re-submitted the design using a well-known program he had developed himself. The design was again rejected on the ground that the program was not a pre-approved program. The professor finally gave up.

Some years ago, the author prepared a simple design for government approval. It involved some minor temporary cut slopes with a sheetpile cofferdam. The proposed cut slopes had a gradient of 30^o and a maximum height not exceeding 0.75m. The author did not prepare any slope stability calculations for the proposed temporary cut slopes, thinking that such calculations would not be necessary because the proposed cuttings were minor and would not a safety threat to the public. The author's judgement was wrong. After submission, full slope stability analyses were required and the slope gradient needed to be further reduced to 26^o to make sufficiently safe to meet the prevailing design standard.

In the early 2000s, a contractor was awarded a foundation contract for installing jacked piles for a government project. There was practically no experience on how jacked pile could be installed to meet the pile acceptance criteria at the time. The contractor managed to negotiate the residual settlement criterion to be waived in the contract and there was also no contract specification to dictate how jacked piles should be installed. The author was appointed by the contractor as consultant for the project. Since there was no contract specification controlling the method of construction, the author had the free hand to develop his own method for installing the jacked piles. Fortunately, some simple methods were developed by the author that enabled the jacked to be installed successfully and could also meet the residual settlement criterion as a bonus. After this successful project, the residual settlement criterion could no longer be waived by the government department for subsequent projects. In addition, a particular specification was developed to control the installation of jacked piles. Additional requirements related to regular calibration of pile jacking machine and re-jacking of installed piles to confirm the performance of completed jacked piles were gradually introduced in the specification. With the many requirements introduced in the specification, jacked piles have become an unattractive foundation option to contractor for future projects.

3.2 McDonaldization of design work

From a commercial point of view, design consultants may actually prefer geotechnical design to be codified, highly regulated and conservative. There are good reasons for this. First, a conservative design has a lower probability of failure and will hence reduce the consultant's professional liability and risk exposure. Second, the consultant can give a good excuse to his client not to adopt an innovative design because of the smaller chance of getting the approval from regulatory authorities although the real reason is probably to save the man-hours needed for developing and defending an unconventional design. Third, McDonaldization of design work, a term borrowed from Ritzer (2000), can be developed when design codes and rigid design guidelines are enforced by regulators.

Proceedings DOI: 10.21467/proceedings.8.2
ISBN: 978-81-688301-1-0

Series: AIJR Proceedings
ISSN: 2582-3922

McDonaldization of design work is important to consultants to remain competitive in their business. It is normally done with the help of standard worksheets for calculations and standard typical details to be used in design drawings. Once the design process has been McDonaldized, the design work can be performed by technicians, inexperienced graduate engineers or perhaps equally well by non-technical staff to reduce staff cost and to achieve higher productivity and profit margin.

McDonaldization has important side effects. People involved in performing McDonaldized design may not need to know or understand the basic concepts or details behind the black-box tools they use for the calculations. They are trained to become proficient engineers, not professional engineers. Engineers trained in this manner may have little interest to learn the fundamentals of geotechnical engineering when the criterion for job promotion is based on proficiency. The author had once the opportunity in a professional interview to ask an engineer who seemed to be quite experienced in geotechnical engineering according to his resume the question: 'What is a marine deposit?'. The author was shocked to hear the answer : 'It is accumulation of rubbish on the seabed'.

4 VALUE OF THEORY

Geotechnical theories are useful despite their limitations provided that they are able to capture certain fundamental behaviours of soils even in an approximate manner. Theories are important in explaining and understanding geotechnical behaviours, assisting designers in developing innovative schemes and guiding engineers in making rational decisions to solve problems on site as illustrated below.

a. Although the classical consolidation theory involves the incorrect assumption of a constant c_v, it can usefully explain the gradual settlement of a clay layer under loading.

b. The wetting band theory involves the big assumptions of constant *D* and *k*, but it can beautifully explain why a deeper wetting front can develop for the less permeable volcanic soils in Hong Kong.

c. It is well established that preloading can reduce primary and secondary settlement of soils although such effects cannot be predicted accurately using available geotechnical theories. The same behaviour is expected to be applicable to pile. Although the approach of subgrade reaction in modelling soils as soil springs is subject to criticism, it does demonstrate that buckling of pile is not an issue even when the pile is embedded in loose sand with a low constant of horizontal subgrade reaction n_h. Given these theoretical findings, a construction method can be successfully developed for installation of jacked H-piles using the technique of preloading to reduce residual pile settlement and sand filling for preventing buckling of pile during jacking (Li 2026).

d. The shear strength τ of an unsaturated soil can be represented using the following equation (Fredlund & Rahardjo (1993).

$$\tau = c' + (\sigma - \sigma_a)\tan\phi' + (\sigma_a - \sigma_w)\tan\phi^b \quad (2)$$

where σ = normal stress, σ_a = pore air pressure, σ_w = pore water pressure, ϕ' = angle of internal friction relative to $(\sigma - \sigma_a)$ and ϕ^b = angle related to shear strength relative to matric suction $(\sigma_a - \sigma_w)$. The matric suction of soils in a slope can be very high and exceed 100 kPa during a dry season or when the surface of the slope is protected by a hard surface (e.g. Sweeney 1982). The apparent cohesion represented by the term $c' + (\sigma_a - \sigma_w)\tan\phi^b$ may be significant enough to maintain stability of a steep slope. This can explain when old steep chunam slopes can remain stable for decades. The shear strength of soils can drop quickly when the soil suction is lost due to rain infiltration and this can explain when rain-induced shallow failures of slope often occur suddenly without warning.

e. The factor of safety *F* of a dry slope with a planar slip surface is given by the following expression.

$$F = \frac{c'L}{W\sin\alpha} + \frac{\tan\phi'}{\tan\alpha} \quad (3)$$

where c' and ϕ' = effective strength parameters of soils, L = length of slip surface, W = weight of soil wedge and α = slope angle. L is proportional to the slope height h. W is related to the area of the soil wedge and is hence proportional to h^2. The second term of Eq.3 is constant and the first term is inversely proportional to slope height h. Some important implications on slope design can be made from just the simple equation of Eq.3. For large slopes, i.e. when h is large, the first term is insignificant and an increase in factor of safety can only be achieved by having a gentler slope. For a steep slope, a high factor of safety can only be achieved when the slope height is small and the first term of Eq.3 becomes more significant. Despite its simplicity, Eq.3 is extremely useful for preliminary design of slopes and making the decision on whether more rigourous slope stability analyses need to be carried out. This equation is also a useful quick tool for checking the 'reasonableness' of the results obtained from more detailed computer slope stability analyses.

f. A useful design scheme can often be developed based on some very basic soil mechanics concepts or theories. The retaining wall schemes discussed by Li & Chung (2013) can be used to illustrate this point and they involve a few basic textbook theories regarding earth pressure, stability of retaining wall and bearing capacity. The earth pressure acting on a retaining wall can be estimated using various theories in the literature such as the Coulomb's theory. Figure 4 shows the variation of coefficient of active pressure K_a with the inclination angle of wall back α for a cohesionless sand with angle of shearing resistance $\phi = 35^o$ and wall friction angle of $\delta = 0$ based on the formula in GEO (1982, Figure 17). As compared with a retaining wall with a vertical wall back (i.e. $\alpha = 0$), K_a is larger i.e. ($\alpha < 0$) when the wall back slope forward and smaller when the wall leans backward (i.e. $\alpha > 0$) according to Figure 4.

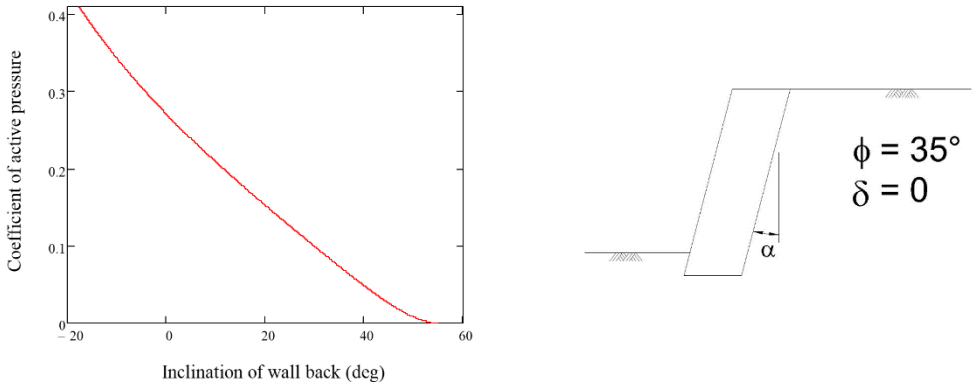


Figure 4: Variation of active earth pressure coefficient K_a with inclination of wall back α

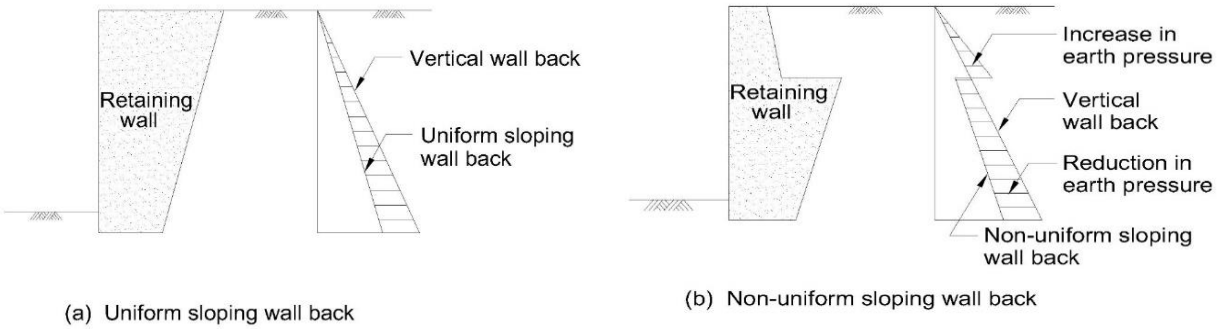


Figure 5: Retaining wall with sloping wall back

Since the earth pressure can be reduced using an inclined wall back, a higher factor of safety against sliding for a gravity wall can be achieved using the wall geometry shown in Figure 5(a). As earth pressure increases with overburden pressure and depth, the highest reduction in earth pressure occurs at the lower portion of the

Proceedings DOI: 10.21467/proceedings.8.2
ISBN: 978-81-688301-1-0

Series: AIJR Proceedings
ISSN: 2582-3922

retaining wall. The wall geometry in Figure 5(a) is not efficient because the upper portion of the wall occupies a larger proportion of the total area (hence a higher material cost) with only a small reduction in active earth pressure. A more efficient geometry can be obtained by a vertical or forward leaning wall back for the top part of the wall as shown in Figure 5(b). It can substantially reduce the cross-sectional area of the wall without significantly increasing the earth pressure.

The cross-sectional area of the retaining wall can be further minimized by reducing the wall width and constructing part of the wall using reinforced concrete as shown in Figure 6. Again, textbook soil mechanics theories are useful in guiding us in modifying the design scheme. The wall base needs to be sufficiently wide to achieve an adequate factor of safety against overturning about the wall toe. The bearing capacity of a shallow foundation depends on its width according to bearing capacity theory. The wall base should be wide enough to achieve the required factor of safety against bearing failure. Higher factors of safety for overturning and bearing failure can be achieved by extending the wall toe as shown in Figure 6.

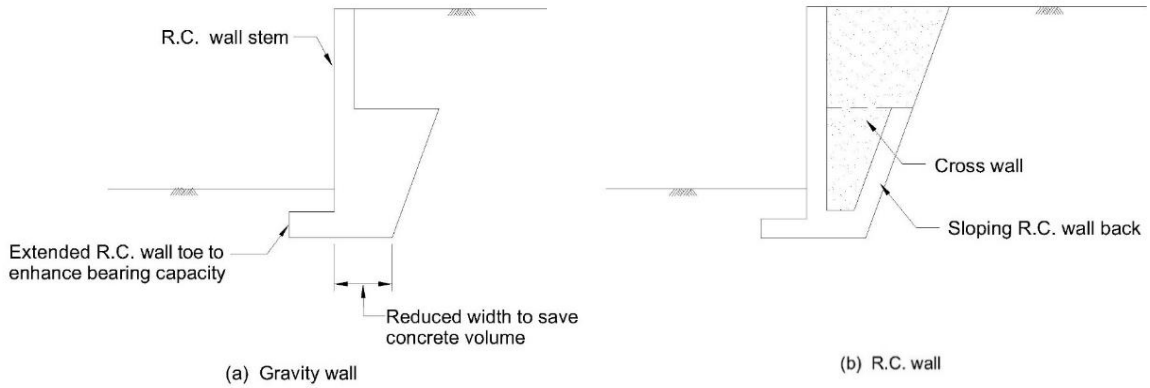


Figure 6: Additional schemes of retaining wall with sloping wall back

Geotechnical design is in many ways like cooking a meal. A good chef (the geotechnical engineer) should have a good knowledge of a wide range of food ingredients and seasonings (fundamental geotechnical theories). He should be able to distinguish good ingredients that can enhance the food from those (the useless theories like Eq.1 for predicting shaft resistance) that can ruin the dish. The chef should be able to choose the right combination of ingredients in preparing a good recipe (the design). A good dish can often be produced just using simple ingredients, like a nice salad prepared from fresh vegetables and a special dressing. The discussions above for a retaining wall with sloping wall back demonstrate that one can go a long way in developing useful design schemes by just a few basic textbook concepts.

5 BRIDGING THEORY AND PRACTICE

The skills needed in bridging theory and practice evolve with time. In the past, site experiences must be gained from spending time on site. In this internet age and new era of artificial intelligence, knowledge site experience can be gained by sitting in front of the computer and using imagination. The following are some suggested ways for bridging theory and practice based on the author's past experiences.

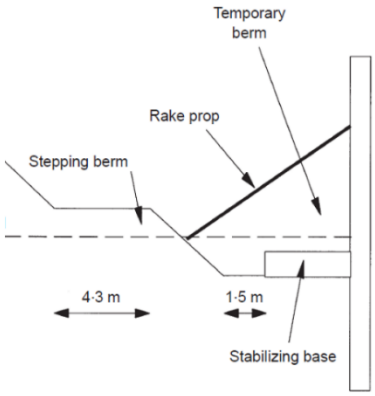
5.1 To keep learning

A good knowledge of theory and practice is an essential requirement for being a competent geotechnical engineer. It is therefore useful to develop a habit of continuous learning as new and useful theories, ideas and practices are constantly developed by others. There are many useful theories that can capture the fundamental behaviours of soils and geotechnical structures, but one should be careful that there are equally many theories which are useless. Eq.1 is a good example of a useless theory. The β value is largely based on past experience. It is like having the answer before doing the prediction. There are also many theories that are toxic. The Asaoka method is a good example of this. It is a deceptively simple and powerful method for predicting the ultimate settlement of a clay layer. On closer examination, it is purely a curve and extrapolation tool. It can be used to

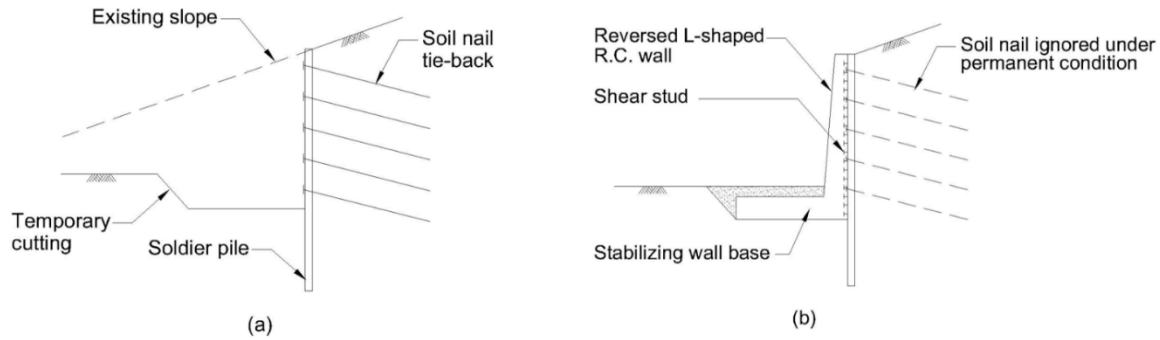
fit almost all data and produce a prediction that can be seriously wrong (Li 2006, 2026). It is often extremely boring to study theories in the beginning. With time, one becomes sharper in identifying theories that are useless or misleading. The study of technical information will then become a much more challenging and interesting exercise.

Information on construction methods in the form of company brochures and youtube videos is widely available on the internet. One can learn how reverse circulation drilling is performed for construction of bored piles comfortably in an air-condition room without having to endure the burning sun on site. However, one must be careful in filtering the information on the internet. Manufacturers who develop the video, for instance, for a particular equipment or construction technique may be biased and do not mention the problems that may occur. There is no excuse for an engineer not to keep learning unless he is content with being a proficient engineer. There are good incentives for doing extensive reading. Civil engineering, of which geotechnical engineering is a branch, is a very old profession. There must be numerous civil engineering papers written on case histories of interesting projects, innovative design schemes, failures, problems encountered with solutions, and etc. There must be some good things in these publications which you can copy, adapt and improve for use in your own projects. The author often says jokingly to his staff, 'don't invent if you can copy (可以抄便不要創作)'. The advantages of copying are well discussed by Earls (2015). Copying enables you to become a geotechnical guru faster because you can develop a better scheme much more easily by improving innovative solutions already developed by others. You can learn about and avoid problems which others have taken many years to discover the hard way.

Figure 7 presents an innovative solution developed by the author based on copying. In 1999, the author read an interesting paper published by Powrie et al. (1999). The paper described a retaining wall scheme (Scheme 1 in Figure 7) involving a contiguous bored pile wall with a stabilizing base. To construct the stabilizing base, a temporary slope berm needs to be maintained initially in front of the wall. A raking prop is then installed to support the bored pile wall before removing the slope berm for construction of the stabilizing base. The raking prop can be removed upon completion of stabilizing base.



Scheme 1: Powrie et al. 1999



Scheme 2: Li & Chung (2013)

Figure 7: Retaining wall with stabilizing base

Proceedings DOI: 10.21467/proceedings.8.2
ISBN: 978-81-688301-1-0

Series: AIJR Proceedings
ISSN: 2582-3922

The concept of a stabilizing base is useful in increasing the height of a retaining wall, but the author does not like Scheme 1 for two main reasons. First, the construction of bored piles on a slope is not an easy task and usually requires a major steel temporary working platform. If a temporary working platform has to be built, it may be easier to adopt a simpler scheme of a cantilever bored pile wall with larger piles. Second, the connection of a new concrete base to the completed bored pile wall is a troublesome task. The author has built on the concept of Scheme 1 and developed Scheme 2 in Figure 7 which is much easier to construct. Steel soldier H-piles supported by tie-backs are used the lateral support system. The soldier piles can be constructed on sloping ground using crawler cranes with a telescopic boom. A reversed L-shaped reinforced wall can then be constructed and integrated with the steel soldier pile wall to form a composite retaining wall. Scheme 2 has now been used for several major projects in Hong Kong with retaining height exceeding 20m in some projects (Li & Chung, 2013; Choi et al. 2021).

5.2 To develop a critical mind

When acquiring new knowledge, one should develop a critical mind in reviewing the information he has learned. He should separate the wheat from the chaff and keep only useful new knowledge in the precious storage space of his brain. One can develop a critical mind by forming a habit of asking 'why', 'why not' and 'what-if' questions in a learning process described as mental Q&A by Li (2026).

By asking 'why', you are trying to make sure that you do understand the technical paper you are reading or to query if there are any mistakes in the paper. You should not accept the information you have learned as useful until you have satisfactory answers to your 'why' questions.

By asking 'why not', you are challenging or deviating from the current practice. Very often, the 'why not' question can lead to a useful outcome. There is a good story to be told about asking 'why not'. A contractor was awarded the contract for the Happy Valley Underground Stormwater Storage Scheme project. The site was located within the Happy Valley Race Course. The original design involved over 500 rock socketed H-piles to resist the flotation of the underground water storage box- structures. To maintain uninterrupted horse racing activities on Wednesdays or Saturdays, the contractor had to remove or relocate the piling equipment before any racing day so as not to obstruct the view of the horse racings. The author was invited by the contractor to attend a meeting to advise on whether the number of tension piles could be reduced. After listening to a short briefing on the project by the contractor, the discussion began by my question of 'why not delete all the piles'. The reason for this question is simple. If there is indeed a method that can be used to reduce the number of piles, it is likely that the same method can be enhanced to enable all piles to be deleted. In the end, subsoil drains were used to reduce the upthrust and all the piles were deleted.

The 'what-if' questions are also useful because it can often spin off to some new ideas and potential issues not discussed or considered in the original research paper, geotechnical design or technical proposal.

5.3 To design for construction effects

The behaviour of a geotechnical structure is significantly influenced by the method of construction as already discussed earlier. One must cater for the likely outcomes in his design. If an annular void around the pile is expected to be formed when constructing a bored pile with a permanent liner, one must make sure that the bored pile is still structurally adequate when the lateral subgrade reaction is expected to be small or close to zero along the permanent liner.

5.4 To be imaginative

Mental simulation is a technique that involves visualizing in the mind about possible outcomes that will occur for a given event. The author finds this technique very useful. When reading a technical paper, one can often get a fair idea of whether the paper is technically sound using this technique. The same technique can also be used to guess the plausible root cause of a problem occurring on site.

When reading the paper by Chu & Yin (2004), one can simulate the construction of soil nails on an existing slope in his mind. One can easily visualize and expect that there will be no radial stress acting on the surface of a stable drillhole. If so, the initial normal stress acting on the soil nails after installation must be small and close to zero. If the test procedures in a experimental cannot replicate the actual initial loading conditions of soil nails,

the results are likely to be misleading. Therefore, one can put a big question on the findings by Chu & Yin (2004) simply on the basis of a mental simulation.

Mental simulation can help to identify the likely cause of ground settlement during excavation within a pipe pile cofferdam. Figure 8(a) and (b) show the typical details of a pipe pile wall. Lagging walls are installed across adjacent pipe piles and sealed by welding. A grout curtain is usually installed behind the pipe pile wall to provide an impermeable barrier to reduce the drawdown and associated ground settlement outside the cofferdam. The voids between the excavated surface and the lagging wall are to be sealed by cement mortar.

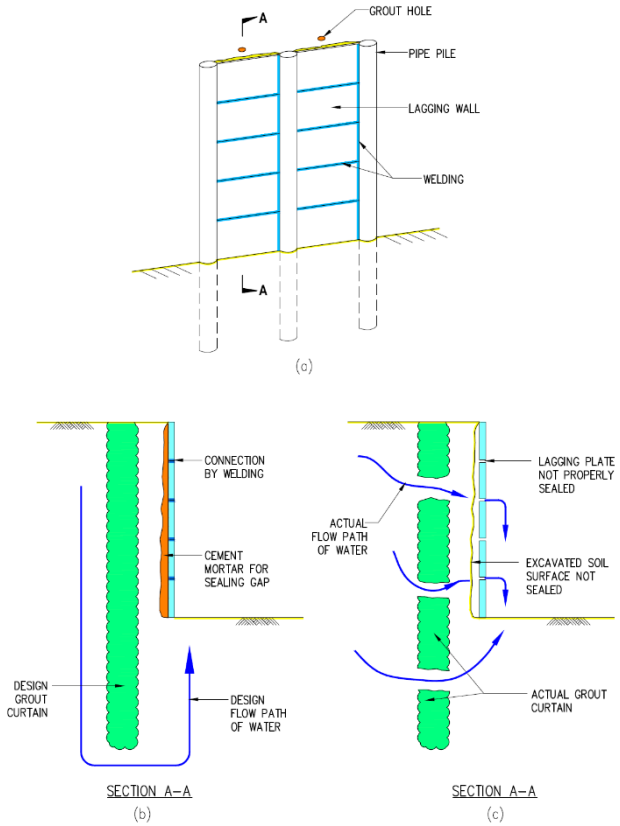


Figure 8: Performance of a pipe pile cofferdam

Proficient engineers who are well trained in producing reports for design submissions often suffer from the problem of tunnel vision. When a problem of ground settlement next to a pipe pile cofferdam occurs, they will often jump to the conclusion that the grout curtain is not deep enough, the struts are not stiff or close enough and so on. It is understandable because these are the issues which they are familiar with and need to deal with day in and day out in their shoring designs in the office. Additional grouting works and/or reduction of vertical spacing of future struts are often specified as the remedial measures for controlling further ground movement. Grouting works require drillholes to be sunk before grouting can be carried out. The drilling operation itself will cause relaxation of ground and hence further ground settlement. The remedial works of additional grouting works often lead to more ground settlement, not less.

Based on the author's experience, the root cause of the problem is usually completely different. If one imagines being the contractor, he can ask himself whether he will diligently carry out the welding to seal the lagging wall and to fill the voids behind the lagging walls with cement mortar. The answer is obvious – 'No'. If one carries out further mental simulation, one can foresee that the actual situation is likely to be similar to what is described in Figure 8(c). The grout curtain may not be continuous due to difficulty in ensuring a perfect continuous grouted zone, deterioration of chemical grout with time or simply poor workmanship. The voids behind the lagging wall are left open and the lagging wall is not sealed by continuous welding. All these will lead to uncontrolled flow of water through the lagging wall and a rapid drawdown of groundwater table outside cofferdam. One can easily verify the finding of the mental simulation by a single visit to the site or asking the contractor to send him a photograph of the lagging wall to see if there is water emerging from the lagging wall.

Proceedings DOI: 10.21467/proceedings.8.2
ISBN: 978-81-688301-1-0

Series: AIJR Proceedings
ISSN: 2582-3922

If the finding of the mental simulation is right, the most effective remedial works will be to seal the lagging walls quickly by welding and fill up the voids behind the lagging wall using a suitably thick cement grout.

The author has recently been asked by a contractor to provide technical advice on proposing some precautionary measures for minimizing potential ground movement of a deep excavation in Central, Hong Kong. The site is surrounded by several live MTR tunnels. Bored piles with left-in steel casings are used as the embedded wall for the cofferdam. Temporary steel lagging walls were to be installed between adjacent bored piles and welded onto the left-in casings in a manner similar to that described in Figure 8(a). The penalty for delay was extremely high for the project. The contractor could not afford any loss of time caused by suspension of works if the observed ground movements were to exceed the allowable limit. Amongst various suggestions made by the author to the contractor, the strongest advice was to limit the construction of lagging walls within a smaller zone each time. The lagging walls must be completely sealed by welding and the voids behind them have to be completely filled up by cement grout. According to feedback from the contractor, the suggestion was effective in preventing leakage of water through the lagging walls. The excavation for the project was completed successfully with very small ground settlements within just a few millimetres.

5.5 To defy convention

With extensive McDonaldization of design work, on-the-job training is focused on producing proficient engineers whose mindset are deeply shaped by the prevailing design rules and practices. They become insensitive to deficiencies which may exist in such rules and practices.

Pile sleeving is a standard technique used to prevent transfer of lateral load from piles onto slopes. The allowable lateral deflection of piles is small, typically 25mm or less. For a sizable slope, failure is unlikely to cannot be triggered by such a small lateral movement. If so, pile sleeving serves no function other than using it as a trick to avoid having to deal with the problem. If pile sleeving has to be used, a more practical approach is to still treat the pile as sleeved in the analysis but do not actually provide the sleeving in construction (Li 2026).

The residual settlement criterion for pile loading test has been used for decades and few will question its usefulness. As discussed by Li (2024), full unloading of piles will not occur for a real structure until the structure is demolished. It is therefore meaningless to impose a residual settlement criterion as part of the pile acceptance criteria. The residual settlement criterion can lead to the absurd outcome that a well performing pile is rejected while a pile with poor performance will pass the loading test (Li 2024).

Geotechnical engineers should critically evaluate the prevailing design rules and practices and be bold to point out the deficiencies. A flawed design rule/practice is more likely to be changed when there is a higher awareness about its deficiency within the geotechnical profession.

5.6 To think out of the box

The constraints for geotechnical designs depend on site conditions. There are no simple rules for tackling the design problems that are applicable to all sites. An innovative design often calls for thinking out of the box.

It is usually thought that deep foundations must be installed using pile equipment, but it is not always the case. Li (2026) discussed a case study in which pipe pile cofferdams are used to support the excavations to reach the bedrock. Rectangular concrete piers resting on the bedrock are then constructed within the cofferdams as foundations for supporting the tall building. The pile cap and the piers are like a wooden stool supported by four rectangular legs with unequal length.

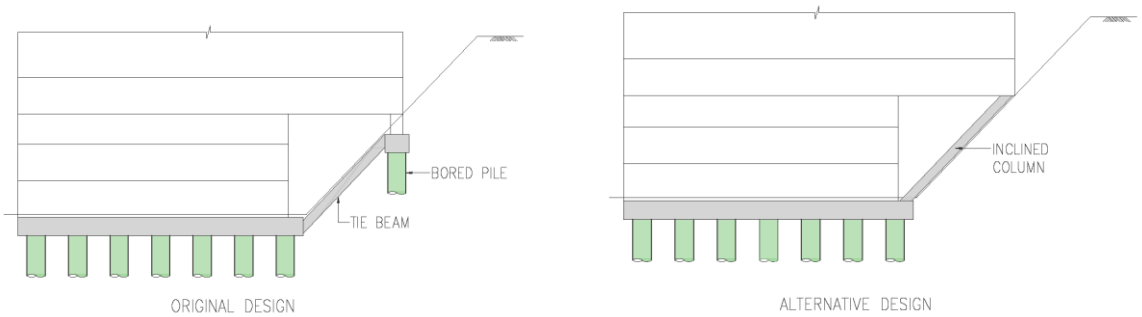


Figure 9: Foundation for building above existing slope

Based on the author's experience, it is often easier to solve a geotechnical problem using a structural solution if feasible. Figure 9 shows a building structure located partially above an existing slope (Li 2026). The original design of foundation involves the use of bored piles to be installed on the slope for supporting the columns along the building edge. A much simpler alternative is to introduce new inclined columns for supporting the edge columns. It is much easier to erect falsework on a slope to construct the inclined columns than to build a major steel temporary platform for the construction of bored piles.

Figure 10 shows another example in which the problem of shoring works is tackled using a structural solution. The structural design of the building requires a screen wall/shear wall to be constructed right along the site boundary as shown in Figure 10(a). It is not easy to develop a conventional shoring scheme for the cofferdam which is water-tight and can enable the boundary screen wall/shear wall to be constructed within the cofferdam. In the end, a special scheme as shown in Figure 10(b) and (c) is developed to enable the screen wall/shear wall to be constructed along the site boundary above ground to meet the design requirement. In this scheme, the pile cap is set back from the site boundary, providing space for sheetpiles to be installed as a water-tight embedded wall to support the excavation for construction of the pile cap. Deep corbels located between the sheetpiles are constructed on the side of the pile cap to support the screen wall/shear wall. The lower part of the screen wall/shear wall is designed as a deep beam serving as the capping beam for the corbels. The remaining part of the screen wall/shear wall will be supported on the deep beam.

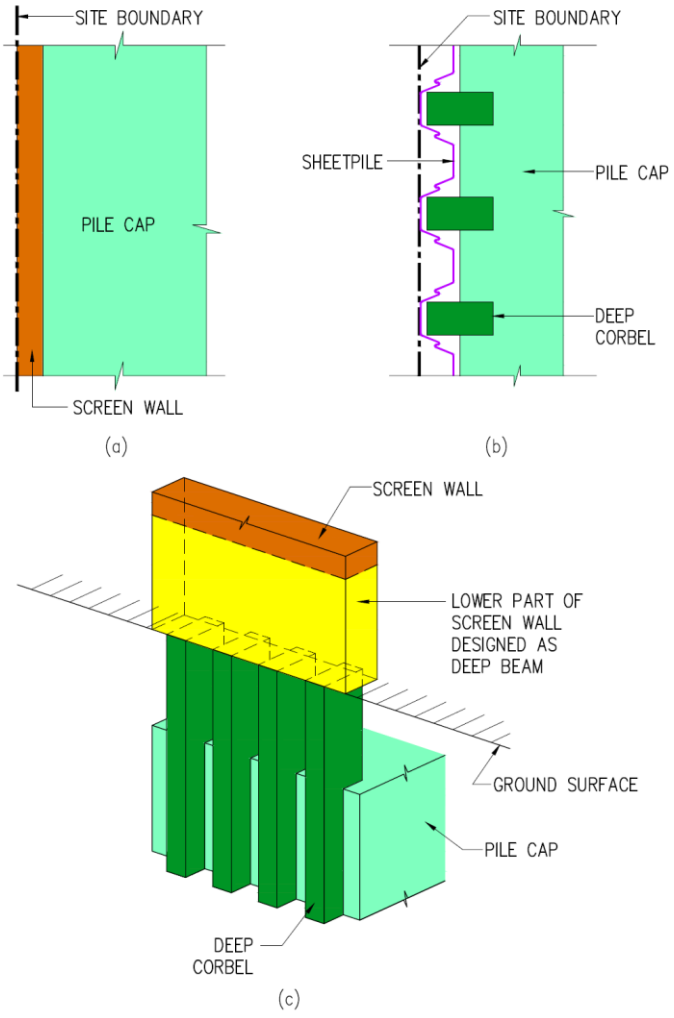


Figure 10: A design scheme for shoring works and pile cap construction

Proceedings DOI: 10.21467/proceedings.8.2
ISBN: 978-81-688301-1-0

Series: AIJR Proceedings
ISSN: 2582-3922

6 CONCLUSIONS

Geotechnical theories cannot have the same precision as laws in physics. They are at best approximations. It is not realistic to expect geotechnical theories to give accurate predictions of the real behaviours of soils and geotechnical structures. One has to make decisions under uncertainty in respect of design, construction and solving problems on site based on imprecise theories and predictions. This makes geotechnical engineering a difficult discipline to master, but at the same time a rewarding profession if one can get a handle on dealing with the uncertainties. Fortunately, there are many useful albeit imperfect theories that can guide geotechnical engineers in formulating sensible design schemes and site engineers in taking the right actions in averting problems on site. One should not be content with just being a proficient engineer, but aim at becoming a professional engineer. To attain this goal, he should be diligent physically in spending time on continuous learning. There are far more good ideas, theories, design method and solutions for solving problems readily available in books and on the internet than one can use in his entire professional career. Geotechnical engineers should also be diligent in his mind to critically review the geotechnical knowledge he has learnt, and accept only those theories, idea, and design methods that can capture the real behaviours of soils and geotechnical structures. One should also be aware of the important effects of construction on geotechnical behaviours. Given the complex nature of soils, the use of a sophisticated program will not necessarily produce a more reliable prediction if the theories or assumptions used in the software are unreal or if the analysis model developed by the engineer cannot reflect the actual method of construction. It is fitting to end this paper by quoting the following insightful remarks made almost half a century ago by Lumb (1980), which are still very true today.

> *In the soil engineering world it is all too easy to spend time on calculating what can be calculated rather than on what should be calculated, to give an overprecise answer to the wrong question.*

PUBLISHER'S NOTE

AIJR remains neutral with regard to jurisdictional claims in published maps & institutional affiliations.

REFERENCES

Choi, K.Y.M., Li, V. & Tam, A.Y.S. 2021. An innovative design of retaining wall in Lung Shan Tunnel construction. *Proc. HKIE Geotechnical Division Annual Seminar*, 31-39.

Chu, L.M. & Yin, J.H. 2005. Comparison of interface shear strength of soil nails measured by both direct shear box tests and pullout tests. *Journal of Geotechnical and Geoenvironomental Engineering*, 131(9): 1097-1107.

Coduto, D.P., Kitch, W.A. and Yeung, M-C. R. 2016. *Foundation Design Principles and Practices*, 3rd Edition. Pearson Education, Inc.

Earls, M. 2015. *Copy*, *Copy*, *Copy*: *How to do smarter marketing by using other people's ideas*, John Wiley & Sons Ltd.

Fredlund, D.G. & Rahardjo, H. 1993. *Soil Mechanics for Unsaturated Soils*, John Wiley & Sons, Inc.

Geotechnical Engineering Office (GEO). 1982. *Geoguide 1 – Guide to Retaining Wall Design, 2nd Edition.*

Geotechnical Engineering Office (GEO). 2006. *Foundation Design and Construction*, GEO Publication 1/2006.

Lam, J. & Li, K.S. 2003. Influence of construction method on shaft friction of bored pile – a case study. *Proc. HKIE Geotechnical Division Annual Seminar*, 142-152.

Li, K.S. & Lo, S.R. 2007. Discussion on 'Comparison of interface shear strength of soil nails measured by both direct shear box tests and pullout tests'. *Journal of Geotechnical and Geoenvironomental Engineering*, 133(3): 344-346.

Li, V. 2006. Analysis of geotechnical data. *Proceedings of Symposium on Hong Kong Soils and Rocks*, Editor: R.P. Martin & K.S. Li, Centre for Research & Professional Development, IMMM and Geological Society of London, Hong Kong Regional Group, 163-196.

Li, V. 2024. A critical review of pile acceptance criteria. *Proc. HKIE Geotechnical Division Annual Seminar*, 189-200.

Li, V. 2026. *Bridging Research and Practice – the VLA Experience, Vol.4 – Foundation Engineering*, Victor Li & Associates Ltd.

Li, V. & Chung, E. 2013. Some useful schemes for retaining wall design for forming building platforms. *Proc. HKIE Geotechnical Division Annual Seminar*, 133-138.

Li, V. & Lo, S-C. 2008. Obstacles to innovative technologies in geotechnical works in Hong Kong. *Proc. HKIE Geotechnical Division Annual Seminar*, 191-195.

Lo, S-C.R., Gnanendran, C.T. & Li, K.S. 2001. The application of numerical analysis to geotechnical engineering projects. *Proc. 14th Southeast Asian Geotechnical Conference – Geotechnical Engineering Meeting Society's Needs*, 3: 383-388.

Lumb, P. 1962. Effect of rainstorms on slope stability. *Symposium on Hong Kong Soils*. Hong Kong Joint Group of The Institution of Civil, Mechanical and Electrical Engineers, 73-87.

Lumb, P. 1980. Thirty years of soil engineering in Hong Kong, Rupert H Myers Lecture, Leura, Australia.

Powrie, W., Chandler, R.J., Carder, D.R. & Watson, G.V.R. 1999. Back-analysis of an embedded retaining wall with a stabilizing slab. *Proc. ICE – Geotechnical Engineering*, 137, April, 75-86.

Ritzer, G. 2000. *The McDonaldization of Society*, Pine Forge Press.

Su, L.J., Chan, T.C.F., Yin, J.H., Shiu, Y.K. & Chiu, S.L. 2008. Influence of overburden pressure on soil-nail pullout resistance in a compacted fill. *Journal of Geotechnical and Geoenvironomental Engineering*, 134(9): 1339-1347.

Sweeney, D.J. 1982. Some in situ soil suction measurements in Hong Kong's residual soil slopes. *Proc. 7th Southeast Asian Geotechnical Conference*, Hong Kong, 91-106.

Terzaghi, C. 1925. Principles of soil mechanics: IV – settlement and consolidation of clay. Engineering News-Record, Nov., 874-878.

Terzaghi, K. 1943. *Theoretical soil mechanics.* John Wiley and Sons, Inc.

Terzaghi, K. 1963. Karl Terzaghi's last writings on soils. *Engineering News-Record*, Nov., 39-40.

Vesic, A.S. 1967. Ultimate loads and settlements of deep foundation in sand. *Proc. Symposium on Bearing Capacity and Settlement of Foundations*, (Editor: A.S. Vesic), 53-68.

Proceedings DOI: 10.21467/proceedings.8.2
ISBN: 978-81-688301-1-0

Series: AIJR Proceedings
ISSN: 2582-3922