THE ROLE OF THE CIVIL ENGINEERING FOR THE CHANGING DEMAND FOR SPACE IN HONG KONG

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Abstract: Hong Kong has traditionally gained space by building taller structures, providing underground space or acquiring additional land. These accomplishments have been achieved by civil engineers and, as a result, Hong Kong has gained a unique status, by being transformed from "*a sleepy tropical port to a bustling industrial city in decades*" (Lumb, P., 1980). This paper outlines some of the recent trends in Hong Kong for space acquisition, such as the recent enactment of the foreshore ordinance, limiting further reclamations, and the Hong Kong government Civil Engineering and Development Department initiative to create underground space. As the scale and complexity of the projects is increasing, civil engineers role to adapt to this requires more specialist input, particularly in the ground engineering field, and the need for project managers to understand these roles and how they interact effectively with other project team members. An overview of past reclamation, slope stabilization, foundations and tunnel projects, typically carried out for space acquisition is provided outlining past incidents and lessons learnt. Future trends in the ground engineering profession are suggested, including the use of information technology, promoting civil engineering, improved project management and sustainability. It is concluded that the complex civil projects achieved in Hong Kong provide a valuable lesson to other challenging projects presently being attempted internationally.

1. INTRODUCTION

"Civil Engineering is the art of directing the great sources of Power in Nature for the use and convenience of man" (ICE, 1828). Given the current complexity and challenges of the civil engineering projects about to commence in Hong Kong, this is statement is becoming more relevant. As "Unforeseen ground conditions were cited as the most significant factor in causing construction delays in civil engineering works" (Chan, W. M. et al, 1995), the nature associated with adverse ground and suitable mitigation measures to overcome these risks is a regular challenge faced for land acquisition. To cope with this, the need for experienced, competent civil engineers and specialists within a project team is imperative. Despite this, defining suitable persons for the job can be difficult especially given the documented complications of getting the right staff and scope appreciation for the risks involved. This paper provides an overview of the key roles ground engineers have within civil engineering, emphasizing that their aims should be to avoid needless risk and over-expenditure.

2. EXAMPLES OF HONG KONG PROJECTS PROVIDING SPACE ACQUISITION

Space acquisition in Hong Kong has been achieved by reclamation; construction on or near steep terrain, requiring slope stabilization; deeper basements and foundations and the creation of underground space. A summary of important past incidents, lessons learnt and future considerations for these types of works are outlined below.

2.1 *Reclamations*

The more significant reclamations, as outlined by Ng, F.H.Y., et al, 2007 and Mackay A.D., 2009, and important engineering considerations are summarized in Table 1. The examples show that in the past reclamations were formed by end tipping without improving the underlying ground causing instability, mainly by mud wave formation at the leading edge of the reclamation. Subsequent reclamations either removed the weaker material beneath the reclamation or installed vertical drains and sand blankets to improve the ground. Despite the advances and knowledge gained in reclamations, they became unpopular in Hong Kong due to the enactment of Hong Kong Government Foreshore Ordinances, requiring stringent environmental impact assessments to be carried out prior to commencing the work, and adverse public opinion resulting from the ongoing Victoria Harbour Reclamation.

Table 1 – Summary of Past Reclamation Projects in Hong Kong (Ng, F.H.Y., et al, 2007)

Reclamation	Date	Remarks
General	1880s to 1950s	Formed by end tipping onto the sea-bed resulting in disturbance to the underlying soft marine deposits with eventual significant differential settlement and instability.
Kai Tak Airport	1952.	Soft marine deposits up to 10m thick were encountered and completely removed beneath the reclamation.
Sha Tin New Town	1960 - 1970	Formed by end-tipping onto soft mud. This caused softening of the mud beneath the reclamation, causing mud wave formation and resulting in long term differential settlement and instability.
Ma On Shan	1980 – 1990	Formed by placing fill in layers over a geotextile placed on the seabed. The reclamation had a reclamation front standing at 1 in 15. As strengthening of the underlying mud was not carried out, mud failure occurred.
Tuen Mun New Town	1980s.	A 240 Ha reclamation underlain by marine deposits up to 15m thick. The dredging and fill replacement was limited to areas requiring foundations. A 1.5m thick marine sand blanket was spread over the mud prior to fill placement.
Tsueng Kwan O	Mid 1980s,	Underlain by marine mud from 5 to 15m thick. Vertical drains were installed into the marine mud and overlying drainage blankets. The marine mud was dredged and geotextile separators placed prior to filling.
Pak Shek Kok	1990s.	A 117 Ha reclamation underlain by 6 to 12m of marine mud. Vertical drains were installed into the marine mud and drainage blankets with geotextile separators placed prior to filling. Mud waves were created during the fill placement, possibly due to overfilling. The subsequent works therefore adopted heavier duty geotextile separators with thicker sand blankets to overcome the instability.

2.2 *Tunneling*

The growing awareness of limited land availability, environmental concerns and the demand to develop underground space has resulted in the construction of numerous tunnels and associated underground structures (Massey, J.B. et al, 2007). Due to the contractual issues arising, few tunnel failures are reported; however some notable incidents, typically reported in local journals, are summarized in Table 2.

Table 2 – Summary of Past Hong Kong tunnel incidents (Massey, J.B. et al, 2007)

Date	Tunnel Location	Remarks
1977	Aberdeen	Excessive groundwater inflows occurred upon encountering a 200m wide geological dyke during excavation.
1977	Wan-Chai	Collapse, associated with drill and blast excavation, upon penetrating a zone with low rock cover with overlying water bearing fill allowing a crown hole to form at the ground surface.
1978	Beacon Hill	A tunnel face collapse associated with excessive groundwater inflow resulted when encountering an abrupt change from strong, moderately decomposed to relatively weak, highly decomposed rock
23.7.83	Sai Wan Ho	Collapse of Shing On Street during construction of the future MTRCL Station
16.12.83	Shau Kei Wan	Collapse of the future MTRCL Shau Kei wan Station during construction
1995	Airport Express	Collapse during drill and blast excavation of the Lantau section
1996	Chai Wan	Flood of the Harbour Area Treatment Scheme (HATS), previously referred to as the Strategic Sewage Disposal System (SSDS) Stage 1 shaft.
2004	Tsim Sha Tsui	Flood of a Cable tunnel during construction upon encountering adverse ground conditions.

Despite the past tunneling incidents, recent projects have become increasingly challenging and through the use of improved risk management strategies and technological advances in mechanized tunneling, have allowed tunnel construction to take place with minimal incidents; an example are the recently completed Kowloon Southern Link (Taylor, J., 2009) and the University of Hong Kong Centennial Campus Underground Salt Water Reservoirs (Mackay, A.D., et al, 2009).

There is a current tunneling boom in Hong Kong initiated by the HK Government Highways Department (HyD) and Drainage Services Department (DSD) and the Mass Transit Railway Corporation Ltd (MTRCL) totaling about HK$ 150 bn investment (Wallis, S., 2008). A summary of the works is outlined in Table 1 and Figures 1 and 2.

Table 3 – Summary of infrastructure networks.

Project / Expected Cost (HK$ bn)	Construction Period	Length (km)	Remarks
West Island Line (MTRCL) / 8.9	2009 – 2014	3	Existing Sheung Wan Station to Kennedy Town with intermediate stations at Sai Ying Pun and University of HK
South Island Line, Central (MTRCL) / ??	2010 – 2015	7	Existing Admiralty Station to South horizons, Ap Lei Chau with intermediate stations at Lei Tung, Wong Chuk Hang and Ocean Park.
South Island Line West (MTRCL) / ??	2011 – 2018	10	Kennedy Town to Ap Lei Chau with intermediate stations at Wah Fu, cyber port and Aberdeen.
Sha tin Central Link (MTRCL) / 37	2010 – 2019	17	Existing Tai Wai to Central Station with intermediate stations at Hung Hom, Diamond Hill, Kai Tak, To Kwa Wan, Ma Tau Wai, Ho Man tin and Wan Chai.
Kwun tong Line (MTRCL) / 4.2	2010 – 2015	3	Yau Ma Tei Station to Whampoa via the Shatin Central Link Ho Man Tin station.

Express Rail Link (MTRCL) / 77	2011 - 2020	30	26km is in tunnel. The line will directly connect to the mainland China rail network.
HK West (DSD) / 2.75	2008 - 2011	11	Tai Hang to Cyberport. The inside diameter ranges from 6.25 to 7.25m and has 8km of connecting adits connecting to 32 drop shafts.
Tsuen Wan (DSD) / 1.12	2009 - 2011	5.1	Tsuen Wan to Yau Kom Tau. The inside diameter is 6.5m with 3 connecting adits.
Lai Chi Kok Drainage (DSD) / 1	2010 - 2011	7	6 to 3m internal diameter with 6 connecting adits and drop shafts.
Harbour Area Transfer Scheme (DSD) / 8	2009 - 2014	19	Depths up to 160m below sea level, internal diameter of 3m running along the north and west coast of HK island from North Point to Ap Lei Chau.
Chek Lap Kok to Tuen Mun (HyD) / 20	2011 - 2016	5.8	Immersed tube tunnel construction across the Urmstorm road-shipping channel and widening of the Tuen Mun highway.
Central Kowloon route (HyD) / 12.5	2010 - 2016	3.8	Dual 3 lane carriageway running from Yau Ma Tei to Kai Tak
Central – Wan Chai Bypass (HyD) / 20.5	??	??	On hold due to reclamation issues.

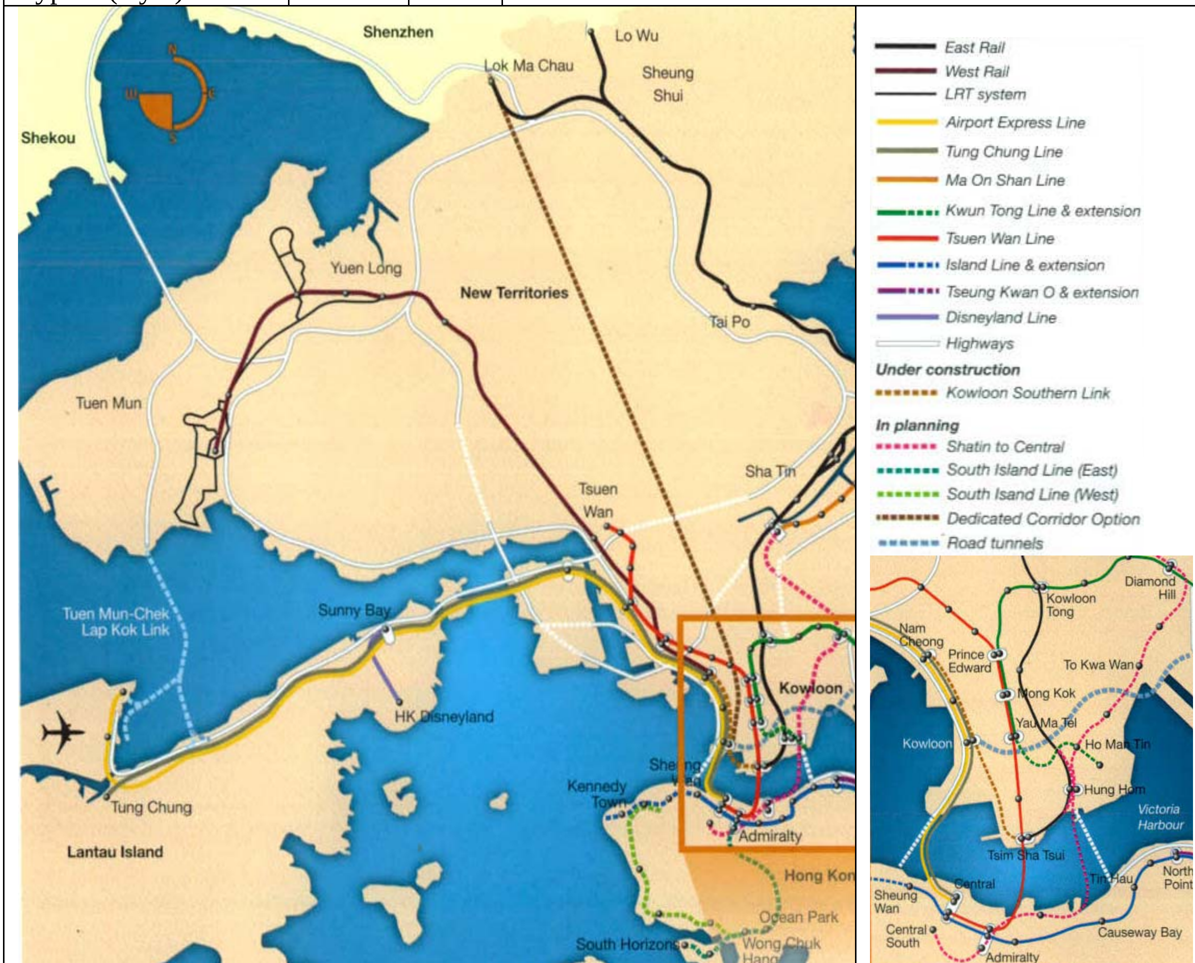


Figure 1. Proposed Hong Kong tunneling projects (Wallis, 2008).

2.3 *Slopes*

Due to the hilly terrain in Hong Kong developments have been formed in close proximity to potentially unstable man-made slopes or natural terrain. By necessity Hong Kong has therefore had a tradition of slope stabilization; a summary of some of the incidents, actions taken and lessons learnt are shown in Table 4.

Table 4 – Summary of Past Documented Slope Instability and Actions taken (Ho et al, 2007)

Date	Volume (m3)	Location	Remarks and initiatives taken
18.6.72	6000 & 20,000	Sau Mau Ping & Po Shan Road respectively	Total 120 fatalities from both landslides resulting from the collapse of fill from a 40m high embankment and of a steep hillside and causing the collapse of a 13 storey residential tower block respectively (See Photo 1)
25.8.76	4000	Sau Mau Ping	18 fatalities in a public housing estate. The Geotechnical Control Office was set up thereafter.
30.7.87	1200	Cho Yiu Estate	Temporary Evacuation of the Residential Estate.
31.8.88	800	Island Road, Aberdeen	The landslide debris had a long travel distance and reached a school complex. The importance of proper engineering geological input to slope stability was highlighted.
11.9.90	19000	Tsing Shan, Tuen Mun	Channelized debris flow on the eastern flank of the Tsing Shan Mountain (See Photo 2). The marginal stability of steep natural terrain in close proximity to developed areas was highlighted.
8.5.92	1500	Baguio Villas	2 fatalities resulting from the collapse of a 6m high wall into a gully impacting the residence below. See Photo 3. The importance of accurate slope cataloging and maintenance, including private owners, was emphasized by implementing the Systematic Identification of Maintenance Responsibilities of Slopes in the Territory (SIMAR) system.
23.7.94	1000	Kwun Lung Lau	5 fatalities resulting from the collapse of a 6m high wall into a gully impact . See Photo 4. The implication of water leakage from utilities within slopes was highlighted.
1.9.01	800	Lei Pui street, Kwai Chung	Channelized debris flow on a natural terrain with debris impacting Lei Pui Street and Shek Lei Estate. Greater attention was given to squatter relocation.

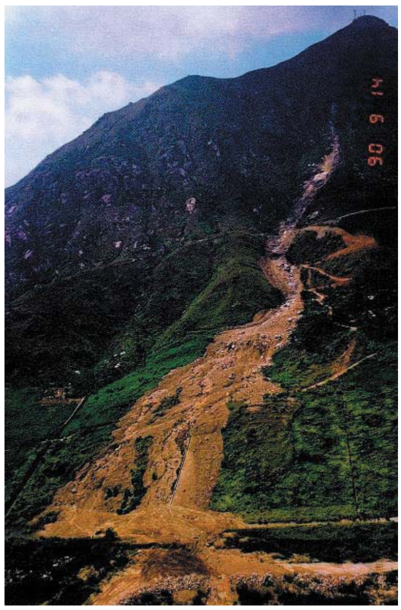


Photo 1 – Po Shan Road

Photo 2 – Tsing Shan

Photo 3 – Kwun Lung Lau

Photo 4 – Baguio Villas

Through the knowledge gained and actions taken for slope instability, its impact to life and economic consequences has been reduced. Notwithstanding, the June 2008 rainstorms caused about 1,600 natural terrain landslides (Wong, H.N., 2009) and provided a reminder of the risks associated with natural terrain instability for Hong Kong and further enhanced the need for the on-going government natural terrain assessment and mitigation works.

2.4 *Foundations and Deep Basements*

The first deep basement excavation in HK extended 6 floor levels below the ground surface, for the New World Trade Centre development in Tsim Sha Tsui, 1976 (Endicott, 2007). A diaphragm wall installation with tie back anchor support to allow excavation was adopted for this excavation and given its success many subsequent installations used similar techniques; failure of the tie backs occurred in some cases. As a result a ban of their use was implemented by the HK Building Authority in 1978. Following this, examples of over 30 incidents of excessive displacement and failure; defined as small (plans area less than 10m2), medium (plan area between 10 to 100m2) and large (greater than 100m2), were catalogued by Man et al, 1992. Two examples of these incidents are summarized in Table 5.

Table 5 – Summary of Past Documented Deep Excavation (Ho et al, 2007 and Man et al, 1992)

Date	Location	Remarks	Remarks
1981	Queens Road, Central	Large sized collapse occurring at the uppermost levels of the support and extending to 9m depth. This was reported to be a due to the sheet piles not being driven to the correct design penetration and removal of the temporary props to allow permanent works to commence.	

1991 Man Lau Medium sized collapse caused by inadequate shoring between the soldier piles (Chan, 1992)

As a result of these incidents, changes to the Building Ordinance were enacted, requiring the submission of suitable excavation and lateral support (ELS) documentation to the Buildings Department. In 1991, specified requirements were outlined in Practice Notes for ELS installation and administrative procedures were introduced by the Geotechnical Engineering Office (GEO) to enhance control (Ho et al, 2007).

During the late 1990s to early 2000s local journals published short pile scandals noting that large diameter piles, designed to be founded on rock, had not reached the required depth. For the worst cases demolition of two completed residential blocks was carried out. The subsequent legislation ensured that enhanced scrutiny and design verification for pile installations was implemented.

3. THE ROLE OF THE GROUND ENGINEERS WITHIN CIVIL ENGINEERING.

Given the complexities of the forthcoming Hong Kong civil engineering projects, and past history of incidents and measures taken to overcome these, the need for experienced ground engineers has never been greater, particularly in identifying and mitigating against risks associated with adverse ground conditions. To be effective, however, specialists with strengths in both civil engineering and engineering geology are required within the project team. As noted by Fookes, 1997, *"It takes a minimum of three years to formally educate a geologist*, or civil engineer, *and a lifetime to gain experience"*. In addition Fookes, 1997, noted that rare individuals are at home in both engineering and geology and that the engineering geologist should remain a separate practice within the service of the civil engineering profession. Specialists within a ground engineering team may be diverse, depending upon the complexity of the work to be carried out, and may include the specialists and respective interactions outlined in Figure 1.

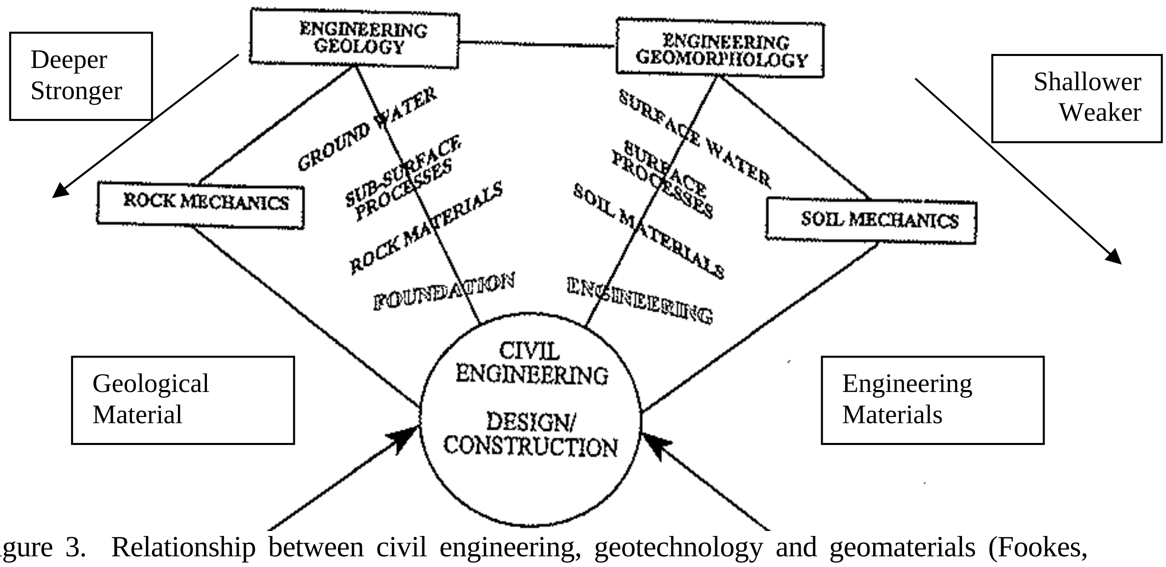
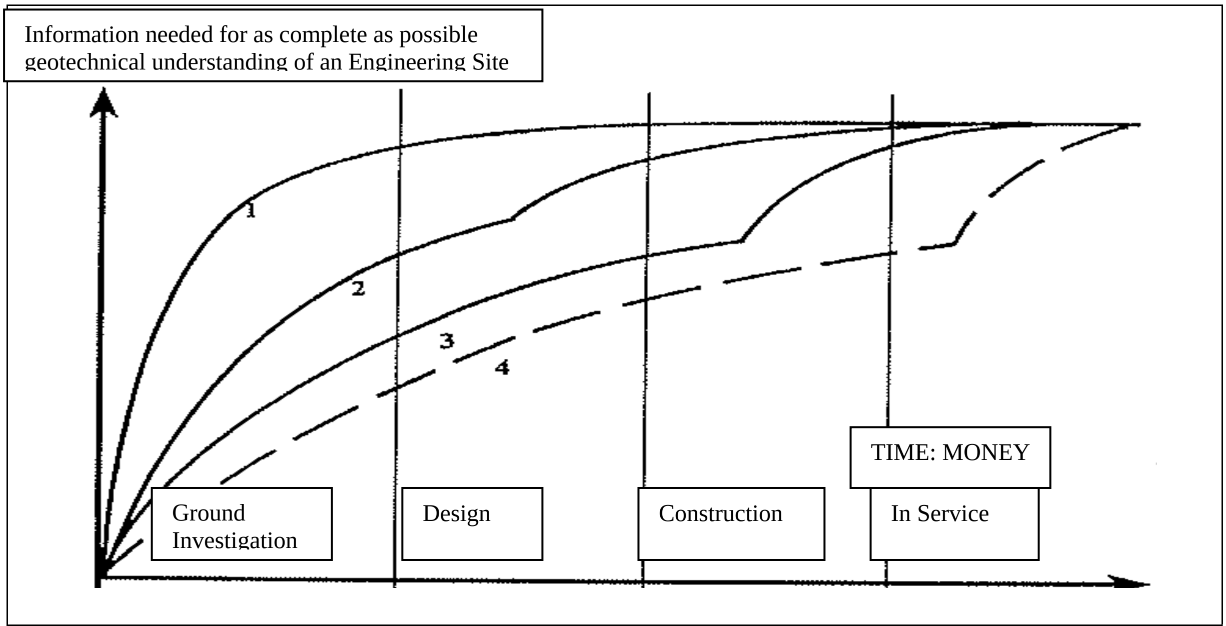


Figure 3. Relationship between civil engineering, geotechnology and geomaterials (Fookes, 1997).

Within a civil engineering project, overlap between engineering geologists and geotechnical engineers may occur during the project design and planning stages. Eddleston et al, 1995 stated that input from engineering geologist should be provided during the initial risk assessment outlining the potential uncertainty of the ground conditions; engineering geologists can therefore significantly influence a project from the outset, as presented in Figure 4.



1. IDEAL – Information available before design
2. NOT QUITE IDEAL – Information still being obtained during design. May cause costly changes.
3. LESS THAN IDEAL – Information still being obtained during construction which may cause expensive design, or construction method changes
4. HIGH RISK SITUATION – Information not discovered by end of construction

Figure 4. Development of confidence in analysis of risk (Fookes, 1997).

An international perspective on the roles of engineering geology and geotechnical engineering, specifically the fields of soil and rock mechanics, was outlined in GEO, 2007. The interaction between these professional affiliations as presented in Figure 5.

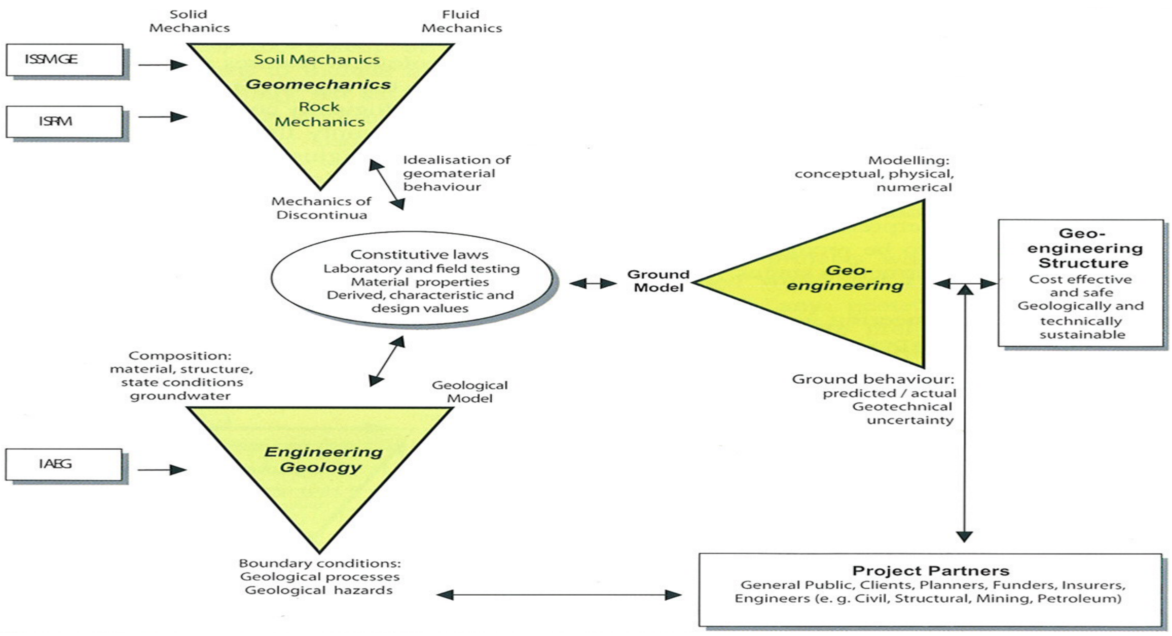


Figure 5. International perspectives of engineering geology, soil mechanics and rock mechanics within "geo-engineering" practice (GEO, 2007).

More recently in Hong Kong frustration has arisen from engineering geologists, who now have an essential role in many of the on-going projects, such as the Natural Terrain Hazard Assessment. The recognized qualification for engineering geology in Hong Kong is the Registered Professional Engineer (Geotechnical, RPE/G), however, this can only be obtained through Corporate Membership of the HK Institution of Engineers, Geotechnical discipline, requiring the applicant to have an engineering degree. It is therefore considered that this vital role is restricted to practitioners with an engineering background, which limits important input from practitioners with a geological background. (Parry, S., et al, 2007).

4. RECENT ADVANCES

Team effort is everything in modern civil engineering and recent advances in ground engineering have been accomplished through positive interaction with other civil engineering specialists; either incorporating their knowledge into ground engineering practice or ensuring others are aware of salient ground engineering factors for each project. Some recent trends relevant to the UK were summarized by Cook, J., 2009, stating that *"London's growing enthusiasm for tall and unusual structures, which maximize below ground space, plus the advent of cross rail and other infrastructure projects, require our ground engineers to be more innovative, rigorous and cost effective – all in a framework of sustainability."* Considering some of these observations recent advances of ground engineering in Hong Kong and internationally are summarized below.

4.1 *Risk Management*

A systematic approach to managing risk was outlined in Tunnel Risk Management in the UK, 1st Edition, which gave guidance on risk sharing for tunnel construction works and outlined the extent of site investigation required for civil engineering projects, previously estimated to be between 1 to 2% of the overall project cost (Eddleston et al, 1995). Baynes, F., 2007 and Clayton,C.R.I., 2001, noted that risk can be categorized as design risk, below ground contract risk and project management risk and the importance of engineering geological input from project initiation was emphasized, as presented graphically in Figure 6.

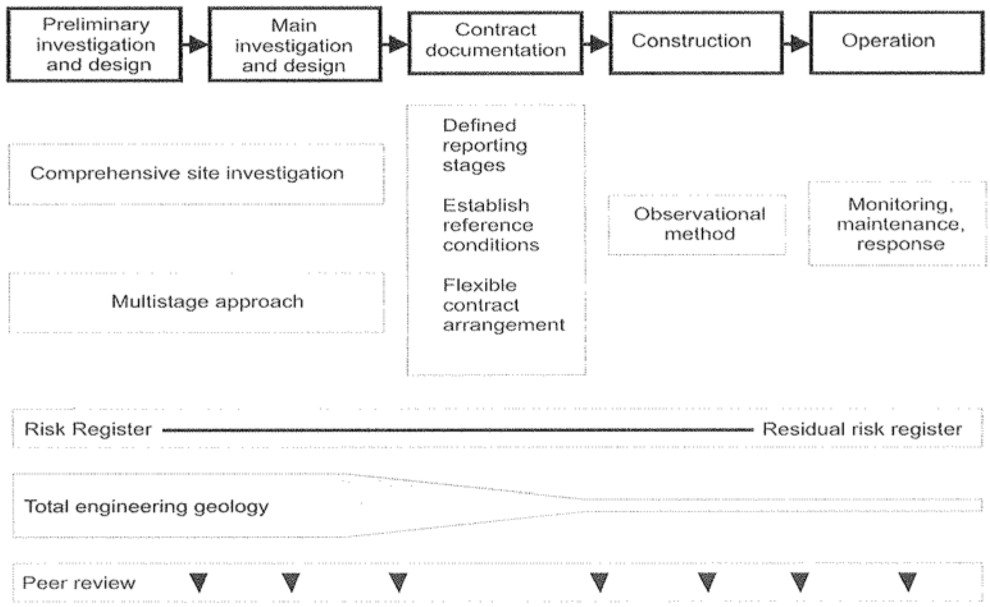


Figure 6. The management of risk at different project stages. (Baynes, F., 2007).

Despite the efforts to implement effective risk management, problems still occur as outlined by Foley, A., 2008, for the overseas Pinherous station collapse, Sao Paolo, Brazil, *"the accident is attributed to a number of deficiencies and omissions in the engineering processes related to the design, construction and management of the project and lack of quality control and risk management."*

4.2 *Information Technology*

Civil Engineers, in particular ground engineers, need to communicate their findings visually. Advancements in Information Technology and information transfer and the improvements in digital photographic quality have assisted processing visual information rapidly, especially three dimensional presentations of ground models and ground and structure interaction.

4.3 *Marketing*

A major concern is that the high standard of professionalism practiced by ground engineers is not disseminated to outside parties, particularly project stakeholders and / or managers. As a result there is a worrying tendency that this work can be "taken for granted", especially internationally. This may be due to the work being sub-surface causing difficulties with visualizing what's there; this contrasts with works above ground which can easily be seen on a daily basis. More frequent visual presentations should be carried out to give a better appreciation of the complexity and extent of the works.

4.4 *Project Management*

Project management is a major risk category in geo-engineering (Baynes, 2007 and Clayton, 2001). As unforeseen ground conditions are the most significant factor causing construction delays in civil engineering (Chan et al, 1995) project managers should have a fundamental understanding of the resources needed, finance, contract arrangements involved to ensure a consistent management approach, implementing relevant aspects of geo-engineering.

4.5 *Sustainability*

Sustainability is an important reason for creating underground space in urban environments (Thomas, T., 2005). The sustainability of the profession however is closely associated with promoting the achievements accomplished and high standards routinely practiced by ground engineers. At present this should be addressed to potential graduates, who often follow other career paths for better financial reward and better image. The sustainability of civil engineering in general is therefore effected by the lack of younger, enthusiastic able graduates willing to view this profession as a long term career path.

5. CONCLUSIONS

The civil engineer has an increasingly important role to play within projects as space acquisition is continually needed in Hong Kong. The diverse backgrounds for practicing ground engineers within civil engineering needs to be better understood, to ensure risk and mitigation against adverse ground conditions is minimized. The perception of ground engineers and civil engineers in general needs to be raised, especially the high degree of professionalism practiced compared with many other professions. Hong Kong has been fortunate in that individuals with a civil engineering background often manage and lead major projects; this example should be followed in other countries. As referenced by Thomas, 2008, following the start of the recession, October 2008, and in the light of numerous headlines of the appalling practices within the financial sector, *"with all these civil engineering projects being driven by public spending it is vital that the upper reaches of project management are placed in the hands of those who can best deal with it. Many of the so-called "money men" have shown themselves to be incapable of managing money in a trustworthy and efficient manner. What hope is there of them managing construction any other way. I genuinely hope that when infrastructure projects get up and running it is engineers at the helm, not bureaucratic financial meddlers who've had their chance – and blew it."*

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