University of Southern Queensland
Faculty of Engineering and Surveying

Construction Technology for High Rise Buildings in Hong Kong

A dissertation submitted by

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TOPIC: Construction technology for High Rise Buildings in Hong Kong

SUPERVISORS: Dr. Qing Liang

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PROJECT AIM: This project seeks to investigate and summarize the construction technology and construction method in Hong Kong High Rise Building. It also discusses the difficulties during construction works and point out common irregularity.

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1. Research the background information related to Hong Kong Construction Industry (esp. Private Sector).
2. Discuss the parties (Authorized Person {AP}, Registered Structure Engineer {RSE}, Registered General Building Contractor {RGBC} and Registered Specialist contractor {RSC}) in Hong Kong construction industry (in Private Sector).
3. Point out the regulation, law, document submission, and monitoring system (government, owner, consultant, and contractor) in Hong Kong.
4. Summarize the general working procedure.
5. Summarize the difficulties occurred in construction site.
6. Summarize the common irregularity occurred in construction site.

As time permits

7. Discuss the site formation works (soil nail, rock dowel, rock bolt, buttress, raking drain, stepped channel, u-channel, staircase and others) in Hong Kong Slope (Landslip Preventive Measures).
8. Discuss the common non destructive test (NDT) in Hong Kong. (e.g. TDR for soil nail, SPT for driven pile, hammer test for concrete strength)
9. Discuss the common destructive test in Hong Kong. (e.g. cube test for concrete strength, tensile test for reinforcement, loading test for foundation, pull out test for soil nail and mini-pile, interface coring for foundation and coring test for concrete strength)

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Abstract

In Hong Kong, owing to the limit space and resources, many technologies were introduced to solve the problem. However, a lot of accident occurred because the technologies were used incorrectly. Hence, Government produces a lot of code of practice (COP) and guidelines to control the construction industry in Hong Kong.

In order to have a better control, Government sets up many regulations and/or ordinances to ensure the construction works running smoothly. Specification, Practical Notes (PN), Guidelines and drawing were produced to ensure the works is completed safety and at high standard.

Owing to misconduct and mistake produced by workers, many tests were used to ensure good quality and workmanship. For example, TDR test was introduced to ensure the length of soil nail fulfil the design. Cube test, core test and hammer test were introduced to check the concrete quality and workmanship. Tensile test was adopted to check the quality of steel. Bleeding test and flow cone test was used to check the quality of cement.

A general procedure of construction works and main point of COP will be introduced in this report. Common irregularities were mention to awake reader attention.

Keywords: Construction Technologies, accident, Hong Kong, Code of Practice, Buildings

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Date

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I would like to thank my job supervisor, Mr. Kwok Choi, CHEUNG for his support during this project. He also provided support in information collection throughout this project.

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Chapter 1 Introduction

1.1 Nomenclature

BD	Buildings Department, A government department to supervise private section’s building, previously called Buildings Ordinance Office (BOO)
CEDD	Civil Engineering and Development Department, A government department
GEO	Geotechnical Engineering Office, A section of CEDD, previously called Geotechnical Control Office (GCO)
ELS	Excavation and Lateral Support
LPM	Landslip Preventive Measures
AP	Authorize Person
RSE	Register Structural Engineer
RGE	Register Geotechnical Engineer
RC	Register Contractor
RGBC	Register General Building Contractor
RSC	Register Specialist contractor
RPE	Register Professional Engineer
NDT	non-destructive test
PN	Practical Notes
PNAP	Practical Notes for Authorize Person and Register Structural Engineer
PNRC	Practical Notes for Register Contractor

TDR Test	Time Domain Reflectometry Test
UBW	Unauthorized Buildings Works

1.2 Background

According to statistic from Hong Kong Government, the area of Hong Kong is about 1100km^2 and the population is about 6.9 million.[1] Therefore, the land resource is very important for Hong Kong people. In such crowed site, high-rise building provides a space for people living. Suitable foundation is needed to support the building.

In Hong Kong, land is very limited and many slopes were noted. Moreover, Hong Kong is always affected by typhoon (June to September). After increment weather, the slope stability will be affected. Therefore, many slopes will collapse after heavy rainfall. (E.g. a lot of people were killed in Kotewall Roadin 18th June1972)[2]. Government spends many resources to upgrade the slope to enhance the slope stability and protect people life.[3].

In Hong Kong, the land resource is limited; therefore, developer/ owner will construct buildings as big (large floor area and high-rise) as they can. Thus, many technologies were used in high-rise buildings (e.g. pre-stressing beam and slab, high strength concrete). Government also provides some benefit to developer when they use new technologies. (e.g. pre-cast facade). Developers also borrow money from bank to buy the land; therefore, they will use a quicker method to reduce the interest. (e.g. table form formwork will be to reduce the time is formwork erection).

Many utilities (communication, electricity, waste water pipe, water supply and gas supply) were underground. Therefore, open cut was seldom used in Hong Kong. Many technologies

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1 http://www.info.gov.hk/info/hkbrief/chi/fact.htm#area (viewed on 1st May 2006)

2 http://zh.wikipedia.org/wiki/%E5%85%AD%E4%B8%80%E5%85%AB%E9%9B%A8%E7%81%BD (viewed on 12th July 2006)

3 http://www.cedd.gov.hk/eng/about/organisation/org_geo_lpd1.htm (viewed on 18th July 2006)

were used in excavation and lateral support (ELS). (e.g. sheet piling, pipe pile wall, grout curtain.) A lot of slopes were near to buildings and access road; therefore, slope stabilization is also very common in Hong Kong. (e.g. LPM works, soil nail, rock dowel, rock bolt, retaining wall, etc.).Government spends a lot of resource to upgrade slopes to enhance the slope safety.

1.3 Aims of this research work.

To discuss the common difficulties/ irregularities and technologies occur in Hong Kong Construction Industry. I do the research work in order to improve the technologies to provide a safe and health environment for worker. I also do the research work to provide a cheap and quick method.

1.4 Layout of this dissertation.

Chapter 1 will present the background information of Hong Kong Construction Industry.

Chapter 2 will review the article before.

Chapter 3 will discuss the construction works in Hong Kong.

In this chapter, the building works will be introduced. The advantage and disadvantage of such works are also mentioned. Some commonly used equipment in Construction Industries will be introduced. Finally, the government control of construction works will be discussed.

Chapter 4 will record the working procedure of construction works

In this chapter, the working procedure for site formation works, foundation works, excavation & lateral support works and superstructure works will be mentioned.

Chapter 5 will mention the common irregularities occur in construction works.

Excessive settlement and wrong excavation procedure are very common in substructure works.

Chapter 6 will discuss the accident prevention measures

Safety talk and training are commonly adopted in Hong Kong Construction Industry in order to prevent accident occur. Government also carried out investigation to find out the causes of accident. In some case, government will establish some guidelines and code of practice to control the dangerous activities.

Chapter 2 Literature Review

2.1 Introduction

The aim of the literature review is to investigate the how contractor and developer to adopted the new technology.

2.2 Developing Innovative Construction

Roozbeh et al. (1997) investigated smart building automation technology (SMART) in the context of the four factors that contribute to innovation: technology fusion, strategic alliances, effective information gathering capability, and reputation through innovation.

1. Strategic Alliances

   In Hong Kong Construction Industry, contractors are part of the developers. Therefore, contractors will introduce new technologies to reduce the construction time and help the developer to reduce construction cost. Many firms have used these strategic alliances to introduce new technologies. For example: precast concrete element, top-down construction)

2. Information Gathering

   In some case, developers also have their design team and construction team. Thus, they can have information gathering. They will review the technology need for the coming years.

3. Reputation through Innovation

   New Technology can decrease the construction time and cost. However, a lot of problem may be occurring. (Example: water leakage in the construction joint between precast façade and concrete element), Thus, developer and contractor, AP and RSE will found a innovative solution to solve the problem.

4. Construction Technology Fusion

In Hong Kong construction, many companies diverse technologies from various disciplines are integrated to develop a new construction technique.

Design Engineers will use computer technology to

1. model the effect in wind in high-rise building;
2. model the landslip in slope improving works;
3. model soil movement in ELS Works.

Engineers also consider using some new material in construction. For example,

4. Glass fibre instead of steel and concrete in slope improving works

Engineers also use other technique in design stage and post construction stages.

5. TDR test was adopted in checking the soil nail bar. Previously, it is used to check the communication cable.
6. Hammer test check the strength of concrete; previously, it is used to check the surface hardness

2.3 New Technology will be adopted from time to time

Samuel et al. (1999) mention that the following:

- Price should drop and more use will be made; with more widespread use comes education and sharing work experience thus promoting further use by engineers in the positions where decisions to use new technologies are made.
- Trenchless technology is highly suited to the installation and rehabilitation of underground utilities in urban environments
- Engineers keep up to date on new advances and were willing to try

new ideas to help lower costs.

Generally, the above opinion was true in Hong Kong. A price is drop when the technology is often used. For example, approximate HK$1500 per meter in drilling soil nail in 1995; however, the current price is HK$350 per meter in drilling soil nail. Trenchless technology is highly suitable to the installation and rehabilitation of underground utilities in urban environments especially in Hong Kong. From my experience, the number for pipe jacking works increase for electricity. Drainage service department (DSD) adopted pipe lining instead of replace a new pipe in drainage works.

2.4 Technology and Constructability

Samuel et al. (1999) mentioned that the main benefit of constructability is

1. Cost reduction to contractor and to the owner
2. Shortening of schedules
3. Improved quality
4. Increased safety

It is also true for Hong Kong Construction Industry. Contractors and developers are seeking a technology to lower the cost, construction time, better quality control and safety-working environment. The accident rate was decreasing in Hong Kong because new technology was adopted. For example, steel sheet piling is adopted instead of timber planking. Bored Piles is adopted instead of hand-dig caisson. Hand-dig caisson was banned in foundation design. Sheet piling installed by hydraulic pressure instead of drop hammer.

2.5 Curtain Wall

Michael et al. 2006 pointed out Structural Insulated Panels (SIPs) can be used to construct an energy efficient curtain wall over timber framing. However,when employed to form a complete wall, wall/roof, or wall/roof/floor system, SIPs can creat a strong , energy efficient building envelope. The insulation capability of SIP construction can be engineered by varying foam type and thickness. Another advantage of SIPs is to produce a higher dimensional quality (Gagnon and Adams, 1999).

In Hong Kong, no such curtain wall system was noted. Glass curtain wall/Aluminium curtain wall/ Aluminium cladding was adopted because the weight is light and light can pass through the glass. The main construction material in Hong Kong Building is Reinforced Concrete; however, no such wood panel was used.

2.6 Limited Resources

Anthony et al. (1992) point out exotic structural systems and construction materials are almost as rare in Japan as in the United States; the materials and methods employed by Japanese counterparts are for the most part recognizable or refinement of their American equivalents. In Hong Kong, similar case was happen. The materials are limited.

Ioannou et al.(1993) also point out that the rising cost of construction is a subject of grave concern to U.S. Industry. Excessive construction costs have eroded the construction industry's competitive position and have led to a decline in capital investment and the growth of manufacturing. Many projects have been abandoned and many are delayed because of shortness of funds. As a result, owners are looking more aggressively more cost-effective design and construction, and contractors are looking into increasing productivity and efficiency to remain competitive.

The expedient introduction of new technology is widely recognized as one of the most promising solutions to these problems because of the potential to enhance quality of the construction project, to increase efficiency, and to decrease cost. New technology provides a driving force to change decisions at the design stage and operations at the construction stage. It is a significant factor influencing design and construction integration integration (Vanegas 1987) and its prudent deployment has a direct influence on the effectiveness of constructability input during design ("Constructability" 1986). Not surprisingly, new technology is the factor that will determine leadership in the world construction markets over the next 20 years (Halpin 1989)

In Hong Kong, many owner and contractor use new technology to increase their profit. For example, Top-down construction method instead of bottom-up method. High strength concrete is used to decrease the size of column/wall.

2.7 Claim and Liquefied Damaged (LD)

According to government statistics (2000), over $235 billion Hong Kong dollars had been spent on major rail, road, land port, and environmental projects over the 5 years leading to 2001. According to the report of the Construction Industry Review Committee (CIRC 2001), many suggestions have been recommended for solving existing delay problems in the construction industry. Some mitigation measures are relevant to reduce the possibility of the common causes of delay in the Hong Kong civil construction industry. However, the effectiveness of them will not be certain until they are actually applied by civil construction practitioners. Tommy Y. et al. (2006) point out that inclement weather, unforeseen ground conditions, inaccurate bills of quantities, and delays in providing design information were the most common causes of delay.

Contractor, AP, RSE and developer will use the new technology to overcome the delay made by previous stage. On the other hand, the contractor may not have enough experience in such technology causing a delay and accident. Therefore, government setup a lot regulation to control the technology.

2.8 Development of Tall Building[4]

It has always been a human aspiration to create taller and taller structures. Ancient structure such as the Tower of Babel, Colossus of Rhodes, the pyramids of Egypt, Mayan temples of Mexico, the Kutub Minar of India and many more were infrequently used.

The history of development of tall building can broadly classified into three periods.

- The first period saw the erection of buildings such as the Reliance Building, the Guaranty Building and the Carson Pirie Scott Department Store. Most of these buildings were masonry wall bearing structures with thick and messy walls. The horizontal and lateral loads of these structures were mainly resisted solely by the load bearing masonry walls. The 17-storey Manadnock Building for example, was built with 2.13 m thick masonry walls at the ground level. The area occupied by the walls of this building level is 15 % of the gross floor area. In addition to reduced floor area, lighting and ventilations are major problems associated with thick wall construction.
- In the second period, with the evolution of steel structures, and sophisticated services such as mechanical lifts and ventilation, limitations on the height of buildings were removed. The demand for tall buildings increased in this period as corporations recognized the advertising and publicity advantages of connecting their names with imposing high-rise office buildings. It was also seen as sound financial investment as it could generate high rental income. The race for tallness commenced with a focus on Chicago and New York. Among the more famous buildings evolved during the period

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4 CHEW, *Construction Technology for Tall Buildings*, Singapore University Press, Singapore, 2001 P1-P.5

were the Woolworth Building and the Chrysler Building. The race ended with the construction of the Empire State Building. The building was 381 meter in height.

- Reinforced concrete established its own identity in the 1950's into the third period which is now regarded as modernism in construction history. In contrast to pervious periods, where architectural emphasis on
- Reasons,
- Functional facts, and
- Technological facts.

This new generation of buildings evolved from World Trade Centre (New York, 1972), Sears Tower (Chicago, 1974) to the recent Twin Towers (Kuala Lumpur, 1996)

Since the height of building increase, therefore the loading of building also increase. The foundation need bigger and sitting on a sound rock. Thus a new technologies is needed in construct the pile (e.g. RCD instead of hand dig caisson) Developer want to decrease the thickness of the wall, then the design need to design a high grade concrete. In the past, 45MPa concrete is consider as high grade concrete; however, 45MPa concrete is very popular used in Hong Kong. For high-rise building, a lot of column use 60MPa concrete when they were casting.

Building Cases	Year	Stories	Slender	kN/m^2	Structural
Empire State Building	1931	102	9.3	2.02	Braced rigid frame
John Hancock Centre	1968	100	7.9	1.42	Trussed tube
World Trade Centre	1972	110	6.9	1.77	Framed tube
Sears Tower	1974	109	6.4	1.58	Bundle tube
Chase Manhattan	1963	60	7.3	2.64	Braced rigid frame

US steal Building	1971	64	6.3	1.44	Shear walls + outrigger + belt
IDS Center	1971	57	6.1	0.86	
Boston Co. Building	1970	41	4.1	1.01	K- braced tube
Alcoa Building	1969	26	4.0	1.24	Latticed tube

Table 1: Efficiency of Structural systems of tall buildings

2.9 Organization

Anthony et. al (1993) mention that all the the comprehensive constructors' building commissions are for complete design and construction services, many of them are, and the trend in this direction is increasing. For this reason, and because design-build commission best illustrate the overall technological capabilities of the comprehensive constructors these projects are worth examining in some detail.

Led by an architect, the team works closely together and meets formally about once a week throughout the design and construction of the project. Junior architects and engineers working on the job are often located in adjacent zones of a large, semiopen office floor. Sometimes the senior team-leader will move their work space to the same area. Close and continuing communication among disciplines, this setup helps achieve the three goals the comprehensive constructors all declare are crucial cornerstones to the project's success: high quality, contained costs, and on-time delivery of the completed building. (Anthony 1993)

In Hong Kong, the owner/ Architect will be the chairman to held a meeting in every week. They will discuss the site matter, design matter, site process and other things in order to ensure the project execute smoothly and hand out the building on time.

2.10 Structural System

Because of the high level of seismicity in Japan, earthquake (and of course gravity) loads govern the structural design of all but the tallest structures, in which wind loads assume prime importance. Although the structural systems used for earthquake resistance in Japanese construction are essentially the same as those employed in the United States, there are more composite and hybrid structural components in use in Japan. To achieve a high level of ductility, most medium- and high-rise construction employs moment or eccentrically braced frame, which are made of reinforced concrete (RC), 'steel-reinforced concrete' (SRC), or steel, depending on the building's height and intended use. SRC refers to an entire composite steel-reinforced concrete system employing either wide-flange shapes surrounded by rebar and concrete, or tubular steel sections filled with concrete. Though precasting is often used in Japanese buildings, pre-stressing and post-tensioning operations are rare.

In Hong Kong, for most residential building, the loading will collect by wall and column and than using transfer plate/ girder to transfer the loading in to column. Then the loading will transfer through the pile cap to the foundation. Transfer Plate is used in order to provide a space for shopping mall and other purpose.

2.11 Working Environment

Anthony et al (1993) also point out that one of the biggest challenges facing Japan's construction industry is finding enough labourers to do the actual work of building. Construction works – from excavating for foundations to applying building finishes – has the reputation of being dirty, dark, and dangerous. These three perceived characteristics of the construction industry, known commonly as the three K's in Japanese, have driven much of Japan's semikilled workforce to safer, "cleaner" jobs in the manufacturing and service industries. Compounding the labour problem is Japan's education system, which produces young adults whose levels of literacy and mathematical proficiency naturally guide them toward more highly skilled position.

In Hong Kong, similar to Japan, the accident rate in construction industry is high. Therefore, government set up law to ensure worker have a reasonable environment.

The law say the owner should do the following:

a) the provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health;
b) arrangements for ensuring, so far as is reasonably practicable, safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances;
c) the provision of such information, instruction, training and supervision as is necessary to ensure, so far as is reasonably practicable, the health and safety at work of all persons employed by him at the industrial undertaking;
d) so far as is reasonably practicable as regards any part of the industrial undertaking under the proprietor's control, the maintenance of it in a condition that is safe and without risks to health and the provision and maintenance of means of access to and egress from it that are safe and without such risks; and
e) the provision and maintenance of a working environment for all persons employed by him at the industrial undertaking that is, so far as is reasonably practicable, safe, and without risks to health.

The law say the employee should do the following:

1) to take reasonable care for the health and safety of himself and of other persons

who may be affected by his acts or omissions at work;and

2) as regards any duty or requirement imposed on a proprietor of the industrial undertaking or on any other person by this Ordinance for securing the health and safety of persons employed at the industrial undertaking, to co-operate with him so far as is necessary to enable that duty or requirement to be performed or complied with.

Since, the working procedure for hand-dig caisson is very dangerous, the hand-dig caisson is banned for new submission.

Precast facade become more and more popular since smaller amount debris was produce. Also it can ensure the working space is more tidy compared with traditional method.

2.12 Construction Automation

There are many construction robots in use in Japan (Levy 1990), including automated concrete finishers, steel welding machines, and facade inspection system. But these systems are not commonly used and often represent incremental gains in both automation and safety. Although the comprehensive constructors (who are leading the automation efforts of Japan's construction industry) have employed automated systems for about 10 years, and are reported by the Obayashi Corp., to have the "most advanced construction robots in the world" most of these system automate one simple construction task, and needed a lot of supervision. The effectiveness of Japan's concrete floor-finishing robots, for example, is reportedly similar to American walk-behind system, and are "an order of magnitude" less effective than American riding trowels. Similar to other country's example, there are no such robot used in construction industry in Hong Kong.

2.13 Computer System used in Construction Industry

Reinschmidt (1991) point out that the structural-design technologies used by the comprehensive constructors are very similar to those in use by medium- and large-size consulting engineering firms in the United States. Finite-element codes are used routinely, and graphic front-end packages are generally impressive but similarto systems available in the United States. CAD is used often but not always. Two-dimensional CAD systems are used for production, while 3-D systems are used by Architects for spatial design and client presentation. The 3-D working-drawing CAD system recently developed by Columbia University's Fletcher "Bud" Griffis, among other, currently has no counterpart in Japan. However, in Hong Kong, 2 major system were used in the drawing. One is "CAD" and other is "microstation". For private sector, "CAD" is the most common software; however, "microstation" is used in government department.

2.14 The Geotechnical Engineering Office Landslip Preventive Measures (LPM) Programme

Since 1976, about $9.7 billion (as of 1 July 2006) has been spent on stability studies and upgrading works in respect of old (i.e. pre-1977) substandard slopes under a long-term programme, viz. the LPM Programme. The Programme provides for the investigation, in a risk-based priority order, of man-made slopes in existence when the Geotechnical Control Office (renamed Geotechnical Engineering Office, GEO, in 1991) was set up in 1977.

The 10-year Extended LPM Project commenced in 2000 and the pledged targets are to upgrade 250 substandard Government man-made slopes and undertake safety-screening studies for 300 private man-made slopes each year up to the year 2010. To pursue the objective of greening man-made slopes, the GEO provides vegetation covers to as many upgraded slopes as practicable and provide about 180,000 plants under the LPM Programme each year.[5]

The technology for soil stabilization works develop very quickly in Hong Kong because Hong Kong Government spent a lot of resource in Slope stabilization works.

Hong Kong Government also spent many resources to investigate the landslip. Government will investigate the accident of landslip and put the information to public, Hong Kong Government also employ the consult engineer to design the landslip preventive works and to investigate the land condition.

2.15 Government Control

Government use the permit to control all construction works in Hong Kong in private sector. The government department that supervises private sector works is buildings Department (BD) [previously called Buildings Ordinance Office (BOO)].

Buildings Department will register the following parties to control the works

- Authorized Persons (List of Architects)
- Authorized Persons (List of Engineers)
- Authorized Persons (List of Surveyors)
- Registered Structural Engineers
- Registered Geotechnical Engineers
- Registered General Building Contractors

[5] http://www.cedd.gov.hk/eng/about/achievements/preventive/index.htm (view on 16 July 2006)

- Registered Specialist Contractors (Demolition Works)
- Registered Specialist Contractors (Foundation Works)
- Registered Specialist Contractors (Site Formation Works)
- Registered Specialist Contractors (Ventilation Works)
- Registered Specialist Contractors (Ground Investigation Field Works)[6]

Approval and Consent

When owner want to have a building works, they must employ an Authorized Persons (AP) as their representative. They also complete the form BA4 to inform Buildings Department. When AP applies the approval, they should submit the drawings and the assessment to environment to BD. If the drawings are fulfilled the legal requirement, BD will give the approval letter and drawing with approval chop. If fail to fulfil the requirement, re-submit is need.

When the works commenced, AP need to apply the consent. At that time, AP need to submit a standard form BA8 to inform BD and get the consent. BD will check the environment again to give the consent.

After AP receives consent (BD103), construction works cannot be start. It is because AP need to inform BD the works will start in 7 days advance and submit a standard form BA10. After the works start, BD will carry out a closely supervision (safety inspection, audit) to ensure the works fulfilled the design assumption. In some geotechnical works, Geotechnical Engineering Office (GEO) also supervises the works.

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6 http://www.bd.gov.hk/english/inform/index_ap.html (viewed on 14 July 2006)

When the works completed, AP need to submit a form BA14, document mentioned in letter of approval (e.g. concrete record, cantilever report (PNAP 173), inspection form for foundation (PNAP242)) and as-built drawings to inform BD.

When a new building is completed, AP needs to submit a standard form BA 13 to inform BD. BD will check the document and the works. If no problem occurs, BD will grant a Operation Permit (OP) to the Owner.

AP also needs to submit other form when they need. For example, BA7 for urgent works, BA11 for appointment another contractor, BA21 for replace another AP when AP not in Hong Kong.

Supervision and Audit

The Site Monitoring Section (SMS) carries out systematic inspections of all private building sites where building works are in progress with a view to identifying irregularities or contraventions of the works being carried out that might have potential safety hazards to the public or non-compliance with the Buildings Ordinance and regulations and the approved plans.

The inspections focus on site safety and quality related aspects of building works in progress to ensure that relevant provisions of the Buildings Ordinance are complied with. If site safety or quality related irregularities are detected, remedies from Authorized Persons, Registered Structural Engineers or Registered Contractors concerned will immediately be sought and where appropriate, prosecution and disciplinary actions under the Buildings Ordinance against those concerned will be instigated.

The SMS also carries out surprise checks to active construction sites on aspects of structural safety and integrity of foundation and superstructure works. This new strategy for auditing building works helps to bring to light structural safety-related irregularities or procedures and practices that are conducive to substandard building works before they become very costly or impossible to put right.

On receiving reports concerning safety issues arising from the operations of building and demolition sites the SMS carries out emergency inspections and the necessary follow up actions.[7]

Geotechnical Control

One of GEO's major slope safety regulatory functions is to check the design of earthworks to ensure they meet current safety standards. Geotechnical checking is exercised largely through the three District Divisions of the GEO: Mainland West Division, Mainland East Division and Island Division, each of which has responsibility for a geographical region of Hong Kong.

The District Divisions check the adequacy of site formation works, slope upgrading works, earth retaining structures and deep excavations that are designed and constructed by the private sector, public authorities and Government departments.

District Division staff are concerned daily with a range of geotechnical problems relating to projects which are often situated on extremely difficult terrain. Major earthworks are commonplace for building developments on slopes, as are deep excavations on reclaimed land. The staff deal with a large number of submissions and are constantly in direct contact with consulting engineers and architects in the private sector, and with professional staff of other Government departments.

In exercising geotechnical control over private sector projects, the GEO operates through

[7] http://www.bd.gov.hk/english/services/index_new3.html (viewed on 31st Dec 2005)

the statutory authority of the Buildings Department, which approves design submissions made by developer's/owner's designers before construction proceeds. For public works, under Government administrative instructions the District Divisions exercise geotechnical control over the projects undertaken by various Government departments and offices, to the same standard as for private sector projects.[8]

When basement construction occurs, at least two governments supervise the works. The professional staffs will spot check the works was carried out according to the drawing. The staffs also have the knowledge to supervise the job.

Owing to close supervision to use of technology by government, the new technology is used safety and correctly. Government supervise the design stage and construction stage, therefore, it is very safe for public when new construction technology is used.

2.16 Conclusions

In Hong Kong, the land resource is limited; therefore, developer/ owner will construct the buildings as big (large floor area and high-rise) as they can. Thus, a lot of technology was used in high-rise building (e.g. pre-stressing beam and slab, high strength concrete). Government also provides some benefit to developer when they use new technology. (e.g. pre-cast facade). Developers also borrow money from bank to buy the land; therefore, they will use a quicker method to reduce the interest. (e.g. table form formwork will be to reduce the time is formwork erection).

Many utilities were underground. Therefore, open cut was seldom use in Hong Kong. A lot of technology was used in excavation and lateral support (ELS). (e.g. sheet piling, pipe pile wall, grout curtain.) A lot of slopes were near to buildings and access road; therefore, slope

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8 http://www.cedd.gov.hk/eng/services/control/index.htm (viewed on 31st May 2006)

stabilization also very common in Hong Kong. (e.g. LPM works, soil nail, rock dowel, rock bolt, retaining wall, etc.).

New technology will be tried by engineer because the condition of Hong Kong.

Chapter 3 Construction Works in Hong Kong

3.1 Introduction

This chapter will review the most common construction technologies in Hong Kong. For example, deep foundation in foundation works; sheet piling in ELS works; top-down construction method in basement construction; soil nail in slope stabilization works; precast unit in superstructure works; pre-stressing beam and slab in superstructure works and government policy to control technology.

3.1.1 Hong Kong Environment

In Hong Kong, the land resource is limited; therefore, developer/ owner will construct the buildings as big (large floor area and high- rise) as they can. Thus, a lot of technology was used in high-rise building (e.g. pre-stressing beam and slab, high strength concrete). Government also provides some benefit to developer when they use new technology. (e.g. pre-cast facade). Developers also borrow money from bank to buy the land; therefore, they will use a quicker method to reduce the interest. (e.g. table form formwork will be to reduce the time is formwork erection).

3.1.2 Historical Background

It has always been a human aspiration to create taller and taller structures. Ancient structure such as the Tower of Babel, Colossus of Rhodes, the pyramids of Egypt, Mayan temples of Mexico, the Kutub Minar of India and many more were infrequently used.

The history of development of tall building can broadly be classified into three periods.

1. The first period saw the erection of buildings such as the Reliance Building, the Guaranty Building and the Carson Pirie Scott Department Store. Most of these buildings were masonry wall bearing structures with thick and messy walls. The horizontal and lateral loads of these structures were mainly resisted solely by the load

bearing masonry walls. The 17-storey Manadnock Building for example, was built with 2.13 m thick masonry walls at the ground level. The area occupied by the walls of this building level is 15 % of the gross floor area. In addition to reduced floor area, lighting and ventilations are major problems associated with thick wall construction.

2. In the second period, with the evolution of steel structures, and sophisticated services such as mechanical lifts and ventilation, limitations on the height of buildings were removed. The demand for tall buildings increased in this period as corporations recognized the advertising and publicity advantages of connecting their names with imposing high-rise office buildings. It was also seen as sound financial investment as it could generate high rental income. The race for tallness commenced with a focus on Chicago and New York. Among the more famous buildings evolved during the period were the Woolworth Building and the Chrysler Building. The race ended with the construction of the Empire State Building. The building was 381 meter in height.
3. Reinforced concrete established its own identity in the 1950's into the third period that is now regarded as modernism in construction history. In contrast to pervious periods, where architectural emphasis on
   - Reasons,
   - Functional facts, and
   - Technological facts.

This new generation of buildings evolved from World Trade Centre (New York, 1972), Sears Tower (Chicago, 1974) to the recent Twin Towers (Kuala Lumpur, 1996)

Building Cases	Year	Stories	Slender	kN/m^2	Structural
Empire State Building	1931	102	9.3	2.02	Braced rigid frame
John Hancock Centre	1968	100	7.9	1.42	Trussed tube

World Trade Centre	1972	110	6.9	1.77	Framed tube
Sears Tower	1974	109	6.4	1.58	Bundle tube
Chase Manhattan	1963	60	7.3	2.64	Braced rigid frame
US steal Building	1971	64	6.3	1.44	Shear walls + outrigger + belt trussess
IDS Center	1971	57	6.1	0.86	
Boston Co. Building	1970	41	4.1	1.01	K- braced tube
Alcoa Building	1969	26	4.0	1.24	Latticed tube

Table 2: Efficiency of Structural systems of tall buildings

3.2 Technologies used in Hong Kong

Many technologies are adopted to overcome problem. The following technologies/ method were used in Hong Kong.

3.2.1 Top-down construction method

In centre business area (CBA), the buildings general have a basement and connect other building and mass transit railway (MTR). During construction state, top-down and bottom-up method were adopted in construction. Top-down construction method become more popular because it shorter the construction period.

Excavation will carry out without the need for strutting to support the excavation because the slabs act as the horizontal support. Therefore, it is another advantage for top-down construction method.

The difficulties are the limited headroom for excavation. Therefore, a special machine may be need during construction state.

3.2.2 Prestressed Concrete

As the height of building increase, the material and construction will be change to fit the actual need. For example, the reinforced concrete beam will change to prestressed reinforced concrete beam in order to decrease the depth of beam and/ or slab.

Prestressing means the intentional creation of permanent internal forces and stress in a structure or assembly, for improving its behaviour and strength under service conditions. Since concrete is strong in compression and weak in tension, prestreeing the steel against the concrete would put the concrete under compressive stress that could be utilized to counterbalance tensile stresses produced by external loads.

Figure 1: Prestress tendon is post-tensioning slab, Condition of tendon before concreting

Pre-tensioning

High-tensile tendons are tensioned before the concrete casting. When the strength of concrete reaches the designed level, the wires are released to produce compressive stress. Suitable curing can accelerate the strength establishment process of concrete. For example, steam curing.

Post-tensioning

Prestress tendons are checked before concrete casting. The prestressing steel can be introduced after concrete has set by casting in duct-tubes at the appropriate positions that are extracted before the steel is inserted.

The tendons are anchored at one end of concrete unit and stressed by jacking against the other end.

The steel is subsequently grouted under pressure through holes at the ends of the unit to protect it from corrosion and to provide bond as an additional safeguard.

Advantages

Better appearance and durability

More efficiently than RC

Allow for shrinkage creep at the design stage

Longer span

Greater rigidity under working loads than RC

Disadvantages

Higher construction cost due to material and supervision

Maintenance is need after superstructure completed

Broken tendon may kill the worker during prestressing.

3.2.3 Transfer Structure

In order to have a large space for shopping mall, transfer structure will be adopted to transfer the loading to column. Pile caps also a transfer structure in Hong Kong. Pile Caps transfer the loading from column to pile (e.g. H-pile, bored pile, mini-pile, etc)

Figure 2: Concreting works for Pile Cap

3.2.4 Deep Foundation

Sometime, the soil condition is not suitable for high-rise building. A deep foundation (e.g. large diameter bored pile (LDBP), driven H-pile) will be developed to solve this problem.

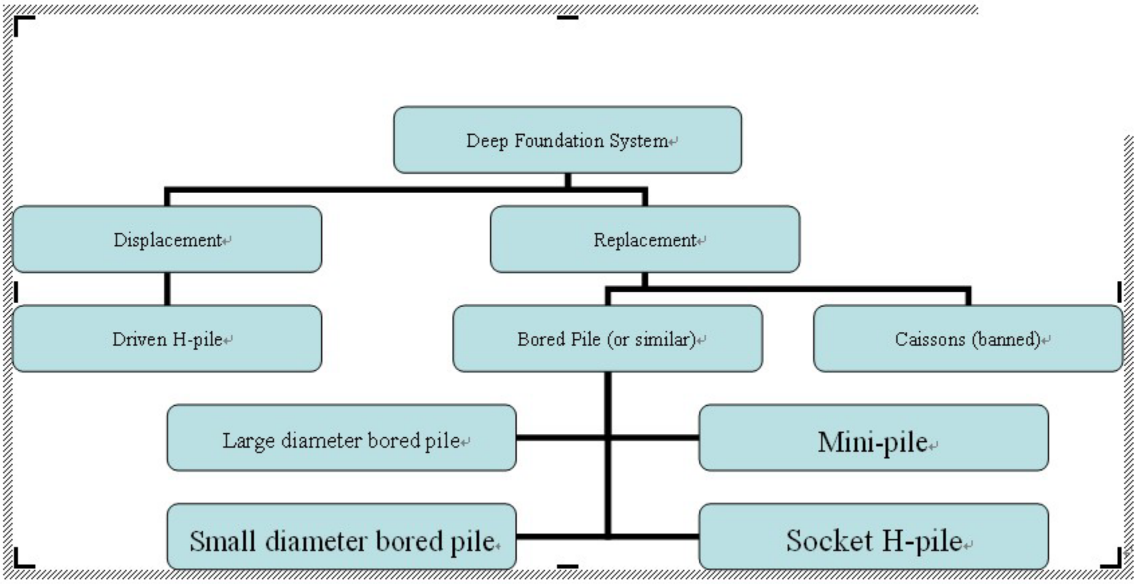

Figure 3: Classification of Foundation in Hong Kong Building

Figure 4: Driven H-pile works in Progress

Ground Investigation (G.I.)

Before foundation works, designer use the G.I. to found out the data for foundation design.

Before actual foundation works (mini-pile, bored pile) commenced, second G.I. (pre-drill) is needed to check the design assumption

After all foundation works (mini-pile, bored pile) completed, third G.I. (post-drill) is need to check the design. Interface coring and proof-drill are needed to check the quality.

Figure 5: Drilling rig is used in drilling works

Figure 6: Drilling rig is used in drilling works

Figure 7: Sample Box to store the coring sample

Mini-pile

Sometime, the location is not suitable for large machine for foundation works. Other construction method will be produced, such as, mini-pile.

Figure 8: Mini-pile was used because of headroom limit

Odex method is used in mini-pile construction works

Large Diameter Bored Pile

Advantages of large diameter bored pile:

a) length can readily be varied to suit the level of bearing stratum

b) Soil or rock removed during boring

c) Less noise and vibration is produced compare with driven H-pile

Disadvantages of large diameter bored pile:

f) expensive compare with footing

g) soil erosion may be occur if the intersection of soil and rock is not horizontal

h) Large machine is needed compare with mini-pile.

Figure 9: Steel casting is used in bored pile works

Figure 10: Equipment is used to ensure the drilling rig vertical

Figure 11: Engineer check the diameter of steel casting before drilling

Figure 12: Vibro hammer is used to insert the steel casting

Figure 13: Machine used to construct the bell out

Figure 14: Chisel was used to overcome the boulder

Figure 15: Reinforcement fixing for bored pile in progress

Figure 16: Excavation works for pile cap and cut-off

Driven H-pile

The construction sequence of H-pile

1. set out the location of H-pile
2. engineer check the setting out, dimension of pile and etc
3. Driven the steel pile
4. Check the verticality
5. Connect the steel H-pile by welding
6. Painting the pile in order to rust-proofing
7. Final-set test is adopted to check the design assumption

Advantages of large diameter bored pile:

a) length can readily be varied to suit the level of bearing stratum

b) Compare with bored pile, H-pile is cheaper

c) No soil or rock were excavated; therefore, transportation of debris is not needed.

d) Settlement of adjacent is usually small compare with large diameter bored pile.

Disadvantages of large diameter bored pile:

a) No Soil or rock removed during driving

b) expensive compare with footing

c) Large machine is need compare with mini-pile

d) Large noise and vibration is produced

e) Longer construction time is needed because only 3 hours per day for divining works

f) Adjacent buildings may be affected due to large vibration

Figure 17: H-piling works in progress

Figure 18: Verticality was checked during H-piling works

Figure 19: Dimension of pile was spot-checked by engineer

Figure 20: Setting out was checked by government

Figure 21: Tell-tale was used to check the movement of cracks

Figure 22: Equipment was used to check the vibration

3.2.5 Shoring

Shoring is the means to provide temporary support to structures that are in an unsafe condition till such time as they have been made more stable.

Figure 23: Shoring was provided to support adjacent building

Figure 24: Shoring was provided to support adjacent building

In Hong Kong, especially in old town, a part of buildings was demolited to redevelop so shoring was very common.

3.2.6 Sheet Piling and Slope stabilization (Geotechnical Works)

In Hong Kong, the buildings are mainly surrounded by other building and slope. Therefore, a lot of technology was used to solve such problem. For example, sheet piling, grout column, grout curtain and pipe pile wall for excavation and lateral support. Soil nail and rock dowel for slope stabilization works.

Figure 25: Sheet piling was installing by vibrating hammer

Figure 26: Sheet piling were installed to protect the existing road in drainage improve works

Figure 27: Pipe Pile Wall is used to support existing buildings in shaft excavation

3.2.7 Demolition Works

Regulation and Practice

- Building (Demolition Works) Regulation 1991
- BS 6187 Code of Practices for Demolition.
- Practice Note for Authorized Persons and Registered Structural Engineers (PNAP) No. 71, 75, 176, 184, 185 & 186.
- Practice Note for Registered Contractors (PNRC)No. 6
- Factories and Industrial Undertaking Ordinance No. 34 of 1991 and subsequent amendments made therein.
- Code of Practice of Handling Transport and Disposal of Asbestos Wastes issued by Environmental Protection Department
- Air Pollution Control Ordinance
- All Public Health Requirements

Video Record of Demolition Works

In October 2001, “World Trade Building” on SZE SHAN STREET was collapsed during demolition. After the investigation, PNRC 51 was produced and video record of demolition works was introduced in buildings. After some years, PNRC 6 was modified.

Video camera to record the entire demolition process should be provided by the RSC for all types of demolition sites. The video camera(s) should be installed at strategic location(s) agreed by the AP/RSE/RGE and be securely protected from being tampered with so that the entire demolition process including the movement of debris and the overall sequence of demolition can be recorded for reference and review purposes.

3.2.8 Site Formation

Soil Nail Works

Soil Nail Works is very common in Hong Kong because Government place a lot of resource to monitor the soil safety and upgrade the slope. (Detail can see “GEO” in this report)

Soil nail head

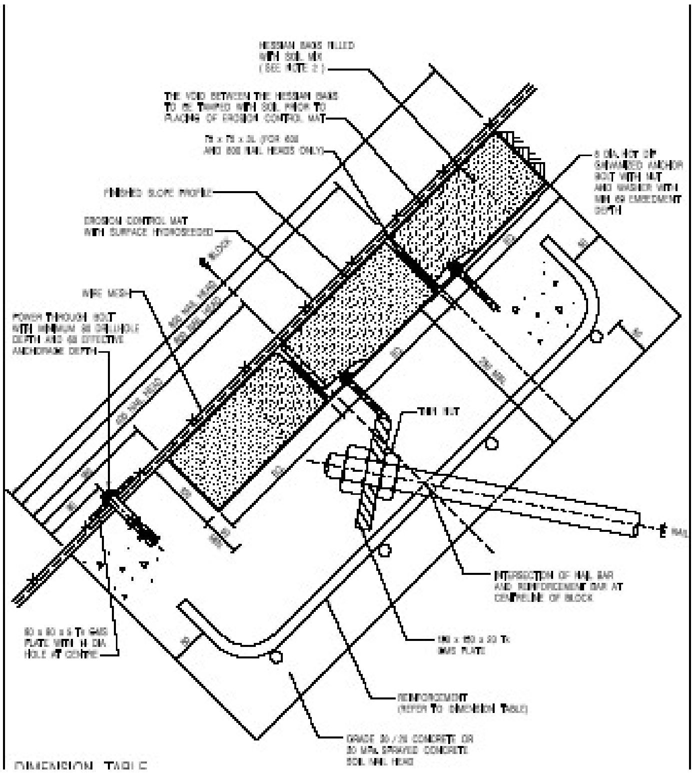

Figure 28: Typical detail of soil nail head

Soil Head is used to protect the soil nail and provide a place for hydro-seeding.

Raking drain

Raking drain should be commenced after the soil nail completed. It is because the raking drain may be blocked by the cement grout if raking drain installed first.

The general procedure of the raking drain is similar to soil nail.

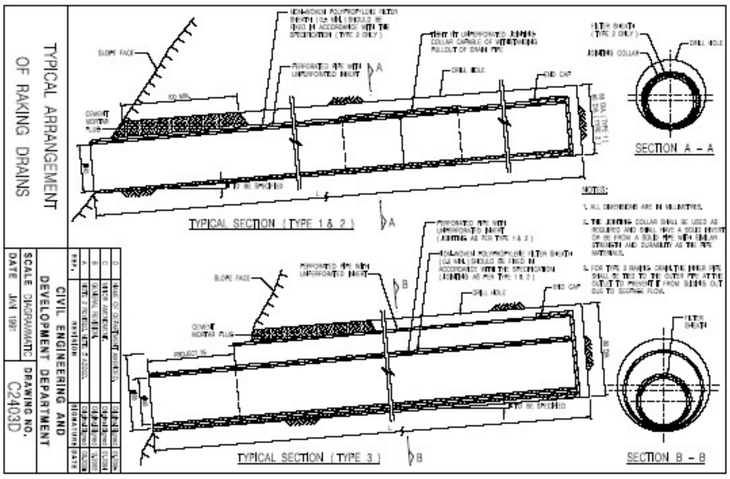

Figure 29: Standard drawing for raking drain

Hydro seeding

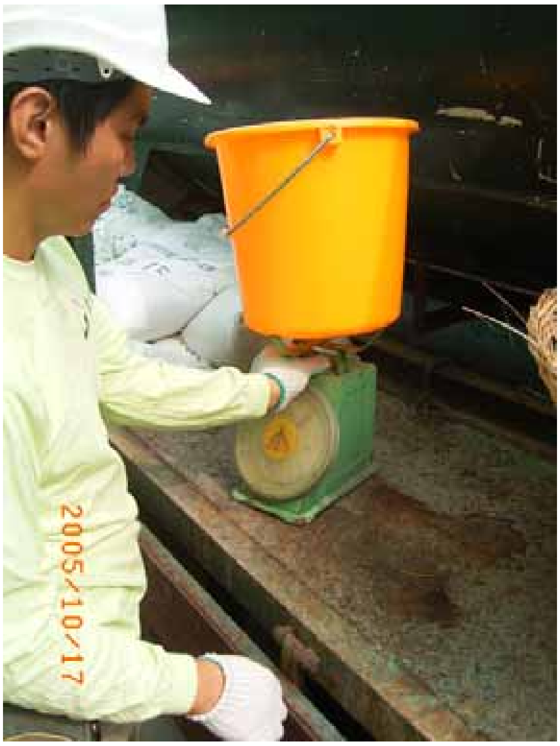

Figure 30: Weight of the grass seed was measured before hydro seeding

Figure 31: General condition of slope after hydro seeding

3.2.9 Superstructure Works

Steel reinforcement is produced in standard length that is governed by the limitation of transportability and weight considerations in bending and fixing. Consequently, there are generally three types of splicing:

1) Lap splicing which is depends on full bond development of the two lapping bars at the lap
2) Mechanical connecting which can be achieved by mechanical sleeves threaded on the ends of the bar to be interconnected. It is used under space limitations or heavy reinforced structural elements.

Figure 32: Coupler is used to connect the reinforement

3) Welding by fusion. However, welding is not recommended when splicing for high tensile reinforcement. Because of the large amount of heat required in the welding process, the properties of the bar will be affected in the area of the weld. If bars are to be welded, the engineer should specify special weldable reinforcement.

In according to the BS 8110, the concrete cover should fulfil the following requirements:

1) Should not less than the main bar or equivalent cross section area if in bundles or less than the nominal maximum size of aggregate..
2) Protect the steel against corrosion.
3) Protect the steel against fire
4) Allow for surface treatments.

Pre-cast façade

Pre-cast façade is very common in high-rise building. It is because government encourage the developer to use such construction method. Sometime, contractor will use precast concrete to reduce the amount of construction waste generated on construction sites, reduce adverse environmental impact on sites, enhance quality control of concreting work and reduce the amount of site labour.

Advantage of pre-cast façade is below:

- Better quality control

Better quality control is achieved because the precast façade was produced in a factory. In where all procedure were closely monitoring

- Less debris produced

It is because all form formwork was the same. It can be recycled. However, in construction site, the formwork may be placed in a wrong position.

- Less noise produced

All the sequences were conduct in factory; therefore, less noise will be produced. For example, hammer hit the formwork.

- Faster construction period

The strength of the pre-cast façade can reach the design strength earlier because steam curing can be used.

Figure 33: Pre-cast façade installation works in progress

Figure 34: Pre-cast façade before installation

Disadvantages of Pre-cast façade

- Damaged during transportation, lifting operation

It can be solve by careful design to ensure the pre-cest faced suitable for lifting up by tower crane.

◆ Water leakage

Water leakage between the construction joints is the major problem in high-rise buildings.

However, it can be solved by the following:

1. a careful design and
2. install a water-stop during concreting on site

Bamboo Scaffolding

Figure 35: Bamboo scaffolding act as a safety mesh/ fence (precaution measure) in high-rise building

Figure 36: Bamboo scaffolding is used as working platform in renovation works
Renovation

Bamboo Scaffolding is very common in Hong Kong Construction Industry because of following reason:

- Easy for erection/ dismantling, and
- Lower price when compare with metal scaffolding

However, a lot of accident was happened in bamboo scaffolding. Therefore, government publishes a code of practice in order to reduce the accident of bamboo scaffolding. Detailed standards of design and construction of some types of simple bamboo scaffold, including double-layered, truss-out and signboard bamboo scaffolds are given in the guidelines with typical examples for each of these types of bamboo scaffold. When the recommended standards are not followed for the design and construction of these types of simple bamboo scaffold or when other types of bamboo scaffold not covered in the guidelines are used, a design engineer with a performance-based design approach should design the bamboo scaffold.

Metal Scaffolding

Couplers are used to attach one tube to another tube at different angles. Compare with bamboo, metal can re-use after a long period use. Therefore, Metal Scaffolding is often used in Hong Kong Construction Industry (especially in soil nail works and falsework in building works)

Figure 37: Coupler used in metal scaffolding

Figure 38: Metal Scaffolding using in soil nail works

3.3 Material Testing

Reinforced concrete is a very common construction material in Hong Kong. Reinforcement is strong in tension; however, it weak in protection against fire and buckling. On the other hand, concrete have opposite properties. Concrete is strong in compression and weak in tension. At the time, concrete also provide a cover to protect the reinforcement.

Reinforcement

It should comply with construction standard 2 (CS2)

Concrete

It should comply with construction standard 1 (CS1)

The strength of concrete is usually tested by core test and cube test. The concrete was sampled on site and produce a core.

Core test: for existing element, shotcrete

Cube test: for cement grout and concrete

Figure 39: Cement cube (100 mm^3) was prepared for testing

3.4 Equipment in Hong Kong's Construction Industry

Air Compressor

Air Compressor is a machine to produce a compressed air to generate power a lot of machine (for example: soil nail drill rig, breaker)

Figure 40: Air Compressor is used in road works to destroy existing concrete slab

Drilling Rig

Drilling Rig is used to drill a hole. Therefore, it is very common equipment in soil nail works and ground investigation works. The power comes from air compressor

Figure 41: Drill rig used in soil nail works

Tower Crane

Figure 42: External climbing Tower Crane

Figure 43: Tower Crane was used in circular-shaped building

Concrete Pump

Figure 44: Concrete Pump for placing ready mixed concrete

Backhoe

Figure 45: Backhoe was used in excavation works

Figure 46: Backhoe was used in excavation works in drainage improve works.

Figure 47: Backhoe was used in sheet piling installation.

Backhoe is usually used as excavator to excavate soil and/or rock in construction site.

Sometimes, backhoe was modified to install sheet piling.

Crane lorry

Figure 48: Crane Lorry was used to deliverer construction material

Grab Lorry

Figure 49: Grab lorry equipped with hydraulic rams and crane was used to deliver rubbish off site

Gantry Crane

Figure 50: Gantry Crane was used to lift up heavy object

Rubbish Chute

A rubbish chute is used to deliver rubbish/ debris off site. Then the debris will be collect by dumper (backhoe/ workers will be needed in loading process) or grab lorry (the debris will be lifted by the mobile crane). In general, debris chute was used to deliver rubbish in building works since the level is very large. However, in some case, the level is large; the contractor will establish a rubbish chute to deliver rubbish off site.

Figure 51: Rubbish Chute was used to deliver Rubbish from High

Figure 52: Collection point was established to collect debris

Hoist

Hoist is mainly used to transport person and material from low to high. These are intended for vertical movement and are move for one direction. The maximum reachable height is virtually unrestricted in theory but depends on the particular hoist design.

Figure 53: Passenger hoist transport worker to appropriate level

Figure 54: Passenger hoist entry at high

Figure 55: Material hoist was used in construction site

Chicago Bomb

It is also a lifting device to deliver object vertically. However, mobile crane and tower crane are most common used in Hong Kong. Therefore, Chicago Bomb is usually used in a small construction site or dismantling tower crane.

Figure 56: Chicago Bomb is used to deliver object vertically.

Mobile Crane

Figure 57: A typical mobile crane with telescopic jib

3.5 Government Control

3.5.1 Registers

Government use the permit to control all construction works in Hong Kong in private sector.

The government department that supervises private sector works is buildings Department (BD) [previously called Buildings Ordinance Office (BOO)].

Buildings Department will register the following parties to control the works

- Authorized Persons (List of Architects)
- Authorized Persons (List of Engineers)
- Authorized Persons (List of Surveyors)
- Registered Structural Engineers

- Registered Geotechnical Engineers
- Registered General Building Contractors
- Registered Specialist Contractors (Demolition Works)
- Registered Specialist Contractors (Foundation Works)
- Registered Specialist Contractors (Site Formation Works)
- Registered Specialist Contractors (Ventilation Works)
- Registered Specialist Contractors (Ground Investigation Field Works)

3.5.2 Approval and Consent

When owner want to have a building works, they must employ an Authorized Persons (AP) as their representative. They also complete the form BA4 to inform Buildings Department. When AP applies the approval, they should submit the drawings and the assessment to environment to BD. If the drawings are fulfil the legal requirement, BD will give the approval letter and drawing with approval chop. If fail to fulfil the requirement, re-submit is need.

When the works commenced, AP need to apply the consent. At that time, AP need to submit a standard form BA8 to inform BD and get the consent. BD will check the environment again to give the consent.

After AP receives consent (BD103), construction works cannot be start. It is because AP need to inform BD the works will start in 7 days advance and submit a standard form BA10. After the works start, BD will carry out a closely supervision (safety inspection, audit) to ensure the works fulfil the design assumption. In some geotechnical works, Geotechnical Engineering Office (GEO) also supervises the works.

When the works completed, AP need to submit a form BA14, document mentioned in letter of approval (e.g. concrete record, cantilever report (PNAP 173), inspection form for foundation (PNAP242)) and as-built drawings to inform BD.

When a new building is completed, AP need to submit a standard form BA 13 to inform BD. BD will check the document and the works. If no problem occurs, BD will grant a Operation Permit (OP) to the Owner.

AP also needs to submit other form when they need. For example, BA7 for urgent works, BA11 for appointment another contractor, BA21 for replace another AP when AP not in Hong Kong.

3.5.3 Supervision and Audit

The Site Monitoring Section (SMS) carries out systematic inspections of all private building sites where building works are in progress with a view to identifying irregularities or contraventions of the works being carried out that might have potential safety hazards to the public or non-compliance with the Buildings Ordinance and regulations and the approved plans.

The inspections focus on site safety and quality related aspects of building works in progress to ensure that relevant provisions of the Buildings Ordinance are complied with. If site safety or quality related irregularities are detected, remedies from Authorized Persons, Registered Structural Engineers or Registered Contractors concerned will immediately be sought and where appropriate, prosecution and disciplinary actions under the Buildings Ordinance against those concerned will be instigated.

The SMS also carries out surprise checks to active construction sites on aspects of structural safety and integrity of foundation and superstructure works. This new strategy for auditing building works helps to bring to light structural safety-related irregularities or procedures and practices that are conducive to substandard building works before they become very costly or impossible to put right.

On receiving reports concerning safety issues arising from the operations of building and demolition sites the SMS carries out emergency inspections and the necessary follow up actions.

3.5.4 Geotechnical Control

One of GEO's major slope safety regulatory functions is to check the design of earthworks to ensure they meet current safety standards. Geotechnical checking is exercised largely through the three District Divisions of the GEO: Mainland West Division, Mainland East Division and Island Division, each of which has responsibility for a geographical region of Hong Kong. Because of its importance to the slope safety system, about a quarter of the GEO professional staff are devoted to geotechnical checking.

The District Divisions check the adequacy of site formation works, slope upgrading works, earth retaining structures and deep excavations that are designed and constructed by the private sector, public authorities and Government departments.

District Division staff are concerned daily with a range of geotechnical problems relating to projects which are often situated on extremely difficult terrain. Major earthworks are commonplace for building developments on slopes, as are deep excavations on reclaimed land. The staff deal with a large number of submissions and are constantly in direct contact with consulting engineers and architects in the private sector, and with professional staff of other Government departments.

In exercising geotechnical control over private sector projects, the GEO operates through the statutory authority of the Buildings Department, which approves design submissions made by developer's/owner's designers before construction proceeds. For public works, under Government administrative instructions the District Divisions exercise geotechnical control over the projects undertaken by various Government departments and offices, to the same standard as for private sector projects.

3.5.5 Landslip Preventive Measures (LPM) Programme

The Geotechnical Engineering Office (GEO) is responsible for carrying out an initial investigation of both Government and private man-made slopes and retaining walls which were formed before the GEO was established and could pose a risk to life or property. The GEO also carries out some major slope upgrading works on behalf of other Government departments.

Since 1976, about $9.3 billion (as of 1 February 2006) has been spent on studies and upgrading works in respect of old (i.e. pre-GEO) substandard slopes under a long-term programme, i.e. the Landslip Preventive Measures (LPM) Programme. This Programme is managed by the Landslip Preventive Measures Branch of the GEO. The LPM Programme provides for the investigation, in a risk-based priority order, of man-made slopes in existence when the Geotechnical Control Office (renamed GEO in 1991) was set up in 1977.

As part of the implementation of the recommendations of the Slope Safety Review undertaken by the then Works Bureau, which were endorsed by the Executive Council in February 1995, the GEO received increased resources to accelerate the LPM Programme. The target is to complete the investigation and the necessary upgrading works on 800 high-priority substandard Government man-made slopes registered in the 1977/78 Catalogue of

Slopes over a five-year period commencing on 1 April 1995 through an increase in the number of in-house staff and engagement of more consultants. Slopes identified in the New Catalogue of Slopes as posing an immediate and obvious danger are also investigated and upgraded under the LPM Programme.

Because of the acceleration of the LPM Programme since 1 April 1995, the output of detailed slope stability studies and slope upgrading works by the GEO has increased significantly. The acceleration of the LPM Programme was originally arranged as a 5-year project. As part of Government's commitment to improving slope safety and its long-term strategy for upgrading and maintaining slope features in the New Catalogue of Slopes, the Project has been extended for another 10 years. This 10-year (2000-2010) Extended LPM Project will deal with high-priority substandard man-made slopes in the New Catalogue of Slopes. The target pledged to ExCo and LegCo in 1998 is to complete the upgrading works for another 2,500 high-priority substandard Government man-made slopes and undertake safety-screening studies for another 3,000 high-priority private man-made slopes by the year 2010. As before, consultants will be engaged in addition to deployment of in-house staff resources to implement the 10-year Extended LPM Project.

It is Government policy to make man-made slopes look as natural as possible to reduce their visual impact and improve the environment. Hence, apart from maintaining the highest standard of slope safety, the GEO is committed to enhancing the appearance of man-made slopes by including this objective as one of the key result areas of the slope safety management system. To pursue this objective, all slopes upgraded under the LPM Programme are provided with landscape treatments and, wherever possible, vegetation is used as slope surface cover and existing vegetation is preserved. A hard surface cover is used only as a last resort on slope safety grounds and as emergency repairs to landslide scars. Where the use of a hard surface cover is unavoidable, landscape measures are implemented to minimize its visual impact as far as practicable. A number of technical guidelines on good practice in slope landscaping works have been published by the GEO. The most comprehensive guidance document is GEO Publication No. 1/2000 - Technical Guidelines on Landscape Treatment and Bioengineering for Man-made Slopes and Retaining Walls. To improve the technology in greening slopes, the GEO has been researching into the use of vegetation in slope works and experimenting with new techniques of providing erosion control measures and vegetation covers to steep slopes. The results of the research provide useful knowledge for establishing robust, cost-effective and eco-friendly vegetation covers for man-made slopes.

Landslip Preventive Measures Branch was seperate into 3 Division:

Landslip Preventive Measures Division 1 (LPM1)

- Implementation of the systematic landslide investigation (LI) programme.
- exercising overall coordination and control of the 10-year (2000-2010) Extended LPM Project, formulating the LPM strategy and master programme, together with monitoring the progress and expenditure of the various LPM projects
- Coordination with other government slope maintenance departments with regard to the interfacing of the LPM Programme and the Enhanced Maintenance Programmes
- Selection and management of LPM consultancies

Landslip Preventive Measures Division 2 (LPM2)

- carry out studies of high priority man-made slopes and retaining walls to identify potential danger and the need for preventive works
- Slope upgrading works designed in-house by the Design Sections are implemented through works contracts managed by the Works Section of the Landslip Preventive Measures Division 3.
- to improve quality and cost effectiveness in the design of slope upgrading works

Landslip Preventive Measures Division 3 (LPM3)

- Prepares tender documents, calls tenders, analyses tenders and supervises in-house slope/retaining wall upgrading works that are designed by GEO's Landslip Preventive Measures Division 2.
- Maintaining and updating a library of sample tender documents for landslip preventive works contracts that serves as reference material for both in-house and consultants' project staff.
- carries out ongoing second-party audits on works in consultant- administered contracts
- carrying out technical assessments of contractors who apply for inclusion onto the List of Approved Suppliers of Materials and Specialist Contractors for Public Works in the category of Landslip Preventive/Remedial Works to Slopes/Retaining Walls

3.5.6 Land Control

As discuss before, the profession and contractor are registered. On the same time, the land resource is also registered. For land, the Lands Department controls the land registration. For slope, the Geotechnical Engineer Office controls the slope registration. Therefore, some sign broad was installed to show the registration number and other relevant information.

Figure 58: The slope registration

Figure 59: Lands Department set up the control point for the level

Figure 60: Lands Department set up the control point for the co-ordination

3.6 Load Estimation in Hong Kong

Hong Kong Building Ordinance mentions the loading in design stage. (detail see Cap(123B))

3.7 Conclusion

Many technologies were adopted in Hong Kong since there are a lot limit (e.g. land resource, adjacent building, high interest rate). Such is good for people to improve the living condition. For example, bored piles produce less noise and vibration. Basement construction method provides more space. Soil nail is used to upgrade the slope stability and provide a good look. Due to there are some advantage and disadvantage, the Government set up a lot of GN and COP to supervise their use. In general, the advantage using such technologies is more than the disadvantage using them. Therefore, government and company are willing to see the new technology. For example, using hydraulic power to install sheet piling become popular in Hong Kong.

Chapter 4 General Working Procedure For construction Works

4.1 Introduction

I will summarize the project that I supervised in the past five year.

Between 2001 and 2004, I work as technical officer (structural) in HKSAR. I supervise the building in private sector on behalf of the Building Authorities (Government). I will point some common irregularities in Hong Kong Construction Industries. (e.g. wrong procedure in excavation works, excessive settlement in foundation works and excavation works, works commenced without approval and consent).

Since 2004, I work as a works supervisor in LPM project. My major role is act as a consult engineer to supervise the LPM works. I will point out the problem occur in LPM works.

I will search the related regulation/ code of practice to find a suitable working procedure and summarize the general procedure of construction works:

4.2 Basement

First, permanent perimeter walls are constructed.

Profounder columns are then constructed, followed by the construction of the ground floor slab.

Profounder columns are columns before excavation. Steel H-section are inserted and concrete to slightly over the lowest basement slab level. The holes are backfilled by sand.

Excavation proceeds downward and basement slabs constructed while construction of the superstructure proceeds in the same time.

Temporary openings are provided on the basement floors to deliver excavated material.

When the design level is reached, contractor constructs the pile caps, beams, etc.

4.3 Site Formation

4.3.1 Soil Nail

Generally speaking, the construction sequence is follow:

1) contractor erect the metal scaffolding (detail can see “metal scaffolding”)
2) contractor’s surveyor setting out the location of soil nail
3) engineer’s surveyor check the setting out
4) contractor construct the test nail in according to approval drawing
5) According to specification, carry out the pullout when the cement strength reaches 21 MPa (N/mm^2).
6) Design engineer check the test result. (i.e. Is it fulfil the requirement of design assumption)
7) Drilling works for soil nail
8) Engineer check
    - the dip angle,
    - dip direction, and
    - the size of drilling rig during drilling
9) Engineer check the drilling record
10) Engineer checks the length of soil nail bar.
11) Carry cement test to check the cement (flow cone and bleeding test)
12) Air flushing to soil nail hole, inserting soil nail bar and grouting.
    - a hole should not be without support 3 days,
    - ensure 300 mm pressure head between grouting and 1 hour after grouting,
    - use heat-shrinking sleeve to protect coupler when coupler is used to connect reinforcement;

- ensure whether the grout pipes are terminated at a point less than 150 mm from the lower end of the steel bar
- Ensure cement grout is injected into the drill holes through the grout pipes with grout return from the drill hole.
- Ensure the water/cement ratio fulfil the specification requirement 0.38 to 0.45)
- Ensure the grout have suitable workability (flow cone test result: time between 15 and 30 second)

13) Sample the cement grout to make a test cube
14) Engineer finish the required document (e.g. grouting record, soil nail bar installation record)
15) Carry out TDR Test to check the length of soil nail
16) Sample the reinforcement for tensile strength test
17) Reinforcement fixing for soil nail head
18) Shotcreting the soil nail head

Figure 61: Engineer check the dip angle during drilling

Figure 62: Size of drilling rig is checked before drilling

Figure 63: Pull out test in progress

Figure 64: Soil nail bar before grouting

Figure 65: Bar mark was checked before grouting

Figure 66: Heat-shrinking sleeve is used protect the coupler

Figure 67: 300 mm pressure head is maintain after grouting

Figure 68: TDR test in progress

4.3.2 Soil Heads

The general procedure of shotcreteing the soil nail head is below:

1) Excavation the soil nail head to design level
2) Placing the reinforcement
3) Placing the first layer sprayed concrete
4) The steel plate shall be fixed after the first layer of the sprayed concrete that should be finished at least 25 mm above the bottom of the steel plate is applied.
5) the steel plate shall then be hammered into position and the nuts tightened
6) apply the second layer sprayed concrete

4.4 Foundation

4.4.1 Large Diameter Bored Pile (LDBP)

The construction sequence of bored pile

1) set out the location of bored pile
2) engineer check the setting out
3) insertion temporary casing for excavation works
4) use vibratory hammer to driven the casing during drilling process
5) Auger will be used in soil
6) RCD will be used in rock
7) Chisels will be used in breaking boulder (however, it is seldom used because a large vibration and noise produced during operation.)
8) Pre-grouting may be used if the soil/ rock interface is not horizontal.
9) Engineers check the condition of rock. (Is it complying with design consideration? Is it match the pre-drilling record)
10) Construct the “bell-out” on the end of the pile

11) Cleaning the pile by compressed air/ and water

12) Check the reinforcement

13) Inserting the reinforcement

14) Grouting

15) During grouting, remove the steel casing slowly with the requirement of specification and approval drawing.

16) Interface coring to check the pile condition

17) Excavation works for pile cap

Figure 69: Chisel is used to overcome underground obstruction

Figure 70: Belling tools used to construct the bell out of bored pile

4.4.2 Mini-pile

Generally speaking, the construction sequence is follow:

1) Contractor use total station/ EDM to locate the setting-out of the piles
2) Carry out the pre-drill to identify the rock head level. (each drill hole represent 5m diameter zone)
3) Resident Engineer (or site staff) check the location of piles
4) Engineer check the site of drilling bits and the size of casing
5) Contractor will use odex method or auger method to construct the pile shaft
6) Contractor collect the rock sample
7) Engineer check the rock sample and verify the rock head level

8) When the excavated level reaches the design level, contractor cleaned the pile shaft.

9) After cleaning, contractor carried out cement tests (flow cone test and bleeding test)

10) Install the reinforcement and grout pipe

  i. When the length is not enough, the reinforcement will be connected by coupler.

11) Grouting the pile

Figure 71: Flow cone test to check the workability of cement grout

Figure 72: Test was measured by stopwatch

4.4.3 Socketted H-Pile

Generally speaking, the construction sequence is follow:

1) Contractor use total station/ EDM to locate the setting-out of the piles
2) Carry out the pre-drill to identify the rock head level. (each drill hole represent 5m diameter zone)
3) Resident Engineer (or site staff) check the location of piles
4) Engineer check the site of drilling bits and the size of temporary casing
5) Contractor will use odex method or auger method to construct the pile shaft
6) Contractor collect the rock sample
7) Engineer check the rock sample and verify the rock head level
8) When the excavated level reaches the design level, contractor cleaned the pile shaft.
9) After cleaning, contractor carried out cement tests (flow cone test and bleeding test)
10) Install the steel H-pile and grout pipe

i. Welding in needed when the length of pile is longer than the length of H-pile

11) Grouting the pile and extract the temporary casing

4.4.4 Driven H-Pile

The procedure of driven H-pile as follow:

1) Contractor use total station/ EDM to locate the setting-out of the piles

2) At the same time, contractor setup monitoring check points (settlement, tiling, and vibration) to monitor the reading of adjacent buildings and/or lands.

Figure 73: Settlement checkpoint was setup to check the settlement

Figure 74: Monitoring the vibration during H-pile Construction Works

Figure 75: Tell-tale adopted to monitor the width of crack

3) Engineer check the size of steel pile and the location of pile

4) Contractor drive the steel pile to the design level

5) Welding is needed when the pile is longer than the length of material

6) Carry out final-set test (measure the displacement per each ten blow)

7) Carry out the loading test to check the pile fulfil the design assumption.

Figure 76: Loading test checking the pile

4.5 Demolition works

In demolition works, contractor should submit the drawing for BD approval. Then, the contractor take to appropriate method to prevent the works affect the public (e.g. hoarding, tarpaulin sheet, nylon mesh, etc). Staff of BD will check the precaution measures and give consent. In general, the demolition sequence is from top to bottom. After complete the demolition, AP need to submit form BA14A to inform building authority.

4.6 Superstructure

4.6.1 Column and wall

Surveyor set out the reference line for worker

Worker fixing the reinforcement of column

Engineer check the reinforcement

Worker erect the formworks

Engineer check the cleanness and formwork

Worker erect the falseworks to support the formwork

Engineer checks the reinforcement, cleanness and workmanship against.

Pumping the concrete

Dismantling the formwork as state at the building ordinance.

Figure 77: Reinforcement for wall before formwork erection

Figure 78: General view of column construction works

4.6.2 Beam, slab, transfer girders, transfer plates, pile cap and similar structure

Surveyor set out the reference line for worker

Worker erect the formwork

Surveyor set out the finish level (F.L.) for worker

Carpenter erect the falsework and formwork

Workers fix the reinforcement

Workers fix the other element such as pile duct and electricity device

Engineer (structural) check the reinforcement and formworks

Engineer (E&M) check the electricity device and other similar thing

Concreting works in progress

Dismantling the formwork as state at the building ordinance.

Figure 79: Reinforcement and other E&M parts checked before concreting

4.7 Excavation and Lateral Support (ELS)

For basement and pile cap works, excavation is needed. However, many utilities are adjacent to construction site. Therefore, temporary support is needed to retain adjacent structure to ensure they are safe. Most common retaining system is adopted in Hong Kong as follow:

(a) Steel sheet piling

(b) Steel channel planking

(c) Pipe Pile Wall

(d) Grout Curtain

The construction procedure for sheet piling and planking are similar as follow:

1) Setting out the location

2) Driven the temporary structure (sheet piling or channel planking) by drop hammer or vibration hammer

3) Install the King Post (if King Post is needed in the temporary works design)

4) Construct the grout Curtain (if Grout Curtain is needed in the temporary works

design)

5) Welding the sheet piling or channel planking

6) Excavate the 1st level of struts

7) Install the struts and waling

8) Continuous excavation to 2nd level of struts

9) Continuous the step (7) and (8) until the design level is reached

The construction procedure for Pipe Pile as follow:

1) Setting out the location

2) Install the temporary casing for the Pipe Pile

3) Construct the Pipe Pile similar to socketted H-Pile

4) Excavate the install lagging wall

The construction procedure for Grout Curtain as follow:

1) Drilling a hole vertically

2) Grouting the hole by cement bentonite slurry

3) Grouting the hole by silicate

Figure 80: Pipe pile adopted as temporary retaining structure in excavation

Figure 81: Soldier Pile and Lagging wall were used in excavation

Figure 82: Steel Sheet Piling was installed as temporary works in excavation

Chapter 5 Irregularity was noted in Hong Kong Construction Industry

5.1 Excavation and lateral support

Locate the Machine in a improper location is the most common irregularity occur in ELS Works

Figure 83: Backhoe was locate in a improper location to excavate the pile cap

5.2 Sheet Piling/ over-excavation

Figure 84: Excavation works at 2nd layer before the 1st layer strut completed

In general, the above irregularity is very common for a small construction site because the following reasons:

- insufficient supervision due to insufficient resources
- faster procedure

5.3 Temporary Slope

Figure 85: Too steep temporary cut slope

The above irregularity is very common for a small construction site because the following reasons:

- insufficient supervision due to insufficient resources
- faster procedure
- less earth works is needed

However, it can produce a large problem:

- slope collapse and kill the worker working at low level
- object fall from height to kill the worker
- affect the adjacent land

Superstructure carried out not comply with approval plan

It is very common because the owner want to have a larger usable area. For example, they may construct a smaller column, thinner wall. In sometime, they may change the method of escape (MOE). Government check the superstructure before OP grant. Government also carry out a spot-check to ensure contractor superstructure works comply with approval plan.

5.4 Excessive Settlement

Excessive settlement may occur in pile construction (speciality in replacement pile)

Odex method excavates the soil and installs the temporary. Hence, it increases the chance of soil erosion and cause excessive settlement on adjacent pavement.

For Large Diameter Bored Pile (LDBP), no temporary casing is need for rock excavation. Soil erosion may occur if the interface between soil and rock is not horizontal.

The excessive settlement can be control by some ELS technique (e.g. Sheet piling and Grouting).

For LDBP, a concrete plug is used to ensure temporary casing sitting on a good surface and prevent soil erosion.

Chapter 6 Accident and their prevention

6.1 Introduction

Accidents are costly not only in terms of human suffering; it also results in loss of production, poor morale and lower productivity. Construction industry has always been one with among the highest accident rate. The temporary duration of works on sites and the rapidly changing character of the work and the workforce have been major problems in terms of safety. A successful accident prevention scheme requires the following four basic activities:

- A risk assessment analysis of all working areas to quantify and control physical or environmental hazards which can contribute to accidents
- A study of all operating methods and practices.
- Provide education, instruction, training incentives and discipline to minimize human factors that contribute to accidents.
- Carry out thorough investigation of every accident. Accident investigation is a defence against hazards that are overlooked in the first three activities, those that are less obvious, or hazards that are the result of combinations of circumstances that are difficult to foresee.

In Hong Kong, a lot of accident was occurring due to a wrong study of all operation method and practices. Such as over excavation in bored pile and mini-pile, wrong working procedure in Excavation and Lateral Support works, excessive movement was produced in driven H-pile and sheet piling installation and over grouting in grout curtain and soil nail works. In Hong Kong, the most common accident is excess settlement/ movement in construction works.

6.2 Government Action

Hong Kong Governments (Labour Department, Buildings Department, and Geotechnical Engineering Office) carries out a deep investigation when a serious accident occurs. After their study, they will give a report and some guidelines to contractor and public to follow. They also use mass media to educate public to concern the problem. For example,

- encourage public to check the slope before wet season
- encourage public to check bamboo scaffolding regularly
- encourage public not to illegal framing in order to reduce the risk of landslip

They also educate the worker in the related industry by information booklet which is free. Government also needs their contractor to provide a safety training and toolbox talks to their worker in order to provide a high standard in safety aspect.

Figure 86: Tool Box Talk was conducted by Safety Officer and Safety Supervisor

Figure 87: Workers listen to Safety Officer's Presentation

Governments also need their contractor to carry out environment assessment during the construction period in order to provide a good environment to public and worker.

Figure 88: Noise Assessment was conducted by Contractor

Government also set up a lot of rule to ensure owner to employ a lot of competent person to supervise the construction works. For example,

- competent person for bamboo scaffolding need check bamboo scaffolding twice per month and submit a report
- competent person for trench excavation need check the trench every week and submit a report
- operator need to check the lifting machine every week and submit a report
- Register Professional Engineer need to check the machine twice per year
- Owner need to employ safety supervisor and safety officer when the size of company reaches certain level.
- In geotechnical works, a CAT3 engineer should be employed to supervise the works
- Technical Competent Person (TCP) system is introduced and ensures certain number qualified person is employed to supervise the quality and safety in private sector.
- A video recording system was introduced to monitoring the site condition
- All workers who working in construction site need have received a basic safety training.
- Competent person should check the confine space before worker enter confine space.

6.3 Conclusion

In Hong Kong, many departments are supervising the construction works; therefore, it is very safe for public.

On the same time, owing to the limiting of land, the height of buildings may be increase useable floor area to increase the benefit.

Chapter 7 Conclusions

7.1 Summary

To sum up, the new technologies were produced when the resource is limited. For example,

1) table form was adopted in formwork erection
2) top-down construction method instead of bottom-up construction
3) deep foundation instead of shadow foundation
4) Pre-cast façade instead of traditional construction
5) Tower crane and mobile crane instead of hoist
6) Ready-mix concrete instead of hand-mix concrete
7) Pre-stress structure instead of R.C. structure

However, a lot of accident happened due to the technology misused. For example,

1) Collapsed formwork in table form
2) Mobile crane and tower crane were collapsed. In 2005, 1 operator was killed in Macau.
3) Over stressing in prestress. Therefore the operator should follow the instruction of the designer

On the same time, the new technologies also improve the living condition. For example:

1) Bored pile instead of driven H-pile
   - Bored pile produce less noise compare with driven H-pile
   - Faster construction time due to longer construction time per day
2) Steel sheet piling in ELS instead of timber piling in ELS
   - Steel sheet piling can provide a better protection for worker working in a trench
3) Use hydraulic method to install sheet piling instead of vibration one
   - The hydraulic method can produce less side effect (e.g. noise and vibration)

4) Precast façade

- It can produced less debris and construction waste

7.3 Further research

After some serious accident happened, a Technical Competent Person (TCP) system was introduced into Hong Kong in 1995.

In 2000, some problem was noticed in foundation works (e.g. poor quality of concreting, the length of pile deviated from design drawing). Quality Supervision Plan (QSP) was introduced in 2001 to monitor the quality.

In 2005, such two plans were integrated into a new supervision plan (TCP2005).

Therefore, further research can be done to find on which state of supervision is better for Hong Kong Construction.

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