Conditions and Constraints in the Formwork Systems for Complex High-rise Building – with cases from Hong Kong

1. Introduction

Formwork systems are among the key factors determining the success of a construction project in terms of speed, quality, cost and safety of works.

Nowadays, most projects are required by the client to complete in the shortest time possible as a means to minimise costs. For high-rise buildings, the most effective way to speed up works is to achieve a very short floor cycle — to have the structure of a typical floor completed in the shortest time. This can be done in Hong Kong within three to four days’ time, even for buildings with floor areas up to 2,500 sq m. The key to achieve this, again from the production point of view, is by the use of a system of efficient and appropriately designed formwork. Modern buildings can be very complex, either in terms of scale, architectural or structural design, sophisticated building services or other facilities requirements. The design and use of the right formwork system, as well as stipulation of an effective resource planning strategy to control and maximise the use of the formwork, are crucial to the overall success of a project.

Aiming purely at speed often contradicts the achievement of other quality targets. Problems such as misalignment, misplacement, defective concrete or holding up other works causing serious interruption can result. This paper, supplemented with several recent Hong Kong case studies, highlights conditions and constraints in the application of formwork, and illustrates the practices and methods that the local construction industry uses to construct complex buildings of various kinds.
2. **Classification of Formwork**

Formwork can be classified according to a variety of categories, relating to the differences in sizes, the location of use, construction materials, nature of operation, or simply by the brand name of the products.

2.1 **Classification according to size**

Classification according to the size of formwork can be very straightforward. In practice, there are only two sizes for formwork; small-sized and large-sized. Any size which is designed for operation by workers manually is small-sized. Very often, the erection process is preferably handled by a single worker, with site work best done independently to avoid possible waiting times. Due to reasons of size and weight, the materials and construction of small-sized formwork are thus limited. The most common systems are made of timber and aluminium, and are usually in the form of small panels.

There is seldom medium-sized formwork. In cases in which large-sized formwork is used, the size of the form can be designed as large as practicable to reduce the amount of jointing and to minimise the amount of lift. The stiffness required by large-sized formwork can be dealt with by the introduction of more stiffening components such as studs and soldiers. The increase in the weight of the formwork panels is insignificant as a crane will be used in most cases.

2.2 **Classification according to the location of use**

Different elements in the structure of building have different design and performance requirements in the use of formwork. A number of formwork systems are particularly designed for constructing internal or external walls, vertical shafts, columns, beams and floor slabs.
However, there are not many effective formwork systems for stairs and staircases. The complicated three-dimensional nature of an element involving suspended panels and riser boards, as well as the need to cope with very different spatial and dimensional variances as required by individual design situations, cannot be achieved by a universally adaptable formwork system (Photo 1).

2.3 Classification according to materials of construction
Materials used for formwork are traditionally quite limited due to finding the difficult balance between cost and performance. Timber in general is still the most popular formwork material for its relative low initial cost and adaptability (Photo 2). Steel, in the form of either hot-rolled or cold-formed sections and in combination with other sheeting materials, is another popular choice for formwork materials (Photo 3). In the past two to three years, full aluminium formwork systems have been used in some cases but the performance is still being questioned by many users, especially in concern to cost and labour control (Photo 4). Other types of metals and alloys are still uncommon on construction sites, due to their cost and easy substitution by other common metals.
Photo 1 – staircase under traditional formwork arrangement using timber

Photo 2 – using of timber formwork in large-scaled project (the Royal Peninsula)

Photo 3 – typical steel form system to construct a core wall

Photo 4 – aluminium formwork for wall, floor and other architectural features
However, the huge amount of tropical wood being consumed each year for formwork has resulted in criticism from environmentalists, as well as the continual escalation of timber prices. As a result, there has been a strong tendency to use other formwork materials or systems to replace timber. At present in Hong Kong, steel form in general seems to be gaining popularity, especially with the incorporation of semi-fabricated construction techniques under design & built arrangement (Photo 5).

2.4 Classification according to nature of operation

Formwork can be operated manually or by other power.lifted methods. Some systems are equipped with a certain degree of mobility to ease the erection and striking processes, or to allow horizontal moment using rollers, rails or tracks.

Timber and aluminium forms are the only manually-operable types of formwork. They are designed and constructed in ways that they can be completely handled independently without the aid of any lifting appliances. However, it is labour intensive and is more appropriate to be used in simpler jobs. On the other end of the scale, such systems are used in very large-sized and horizontally-spread buildings with complicated layout designs which require the systems' flexibility.

Power-lifted formwork can be of the self-climbing and crane-lifted types.

Self-climbing formwork uses built-in hydraulic (Photo 6) or screw jack systems (Photo 7) under full-form or sectioned arrangement. Since the lifting power of the jacks is enormous, a supporting gantry system for the erection of the formwork panels as well as an enclosed scaffold system with inner and outer work platforms are usually provided to form a convenient and self-supporting work station for casting works.
Crane-lifted systems are usually in the form of large panels (sometimes called the gang form). They are fabricated either in steel sections and sheeting, or using plywood sheeting and stiffened by metal studs and soldiers. These large panels can be stood on solid slab or fixed on brackets in case they are used for external walls or shafts (Photo 8).
Photo 7 – example of a self-climbing form using screw jack systems (residential development in mid-level on HK Island)

Photo 8 – typical steel panel type gang forms (commercial complex in public housing development project)

Photo 9 – traveling form used in the construction of an elevated expressway

Photo 10 – gantry-type formwork to form the folded-roof of the airport ground transportation center.
Other forms of operation include the gantry-type, traveling or tunnel form. These are more suitable for use in long repeated sections such as in railway stations, terminal buildings or other large horizontal structures. Recent Hong Kong applications include the construction of the 600 metre-long elevated expressway for the Lantau Link (Photo 9), the Airport Railway's Ground Transportation Centre (Photo 10) and West Rail Siu Hong Station (Photo 11a & 11b).

2.5 Classification according to brand name of the product

Several patented or branded formwork systems have successfully entered the local construction market in the past decade. These include products from SGB, RMD, VSL, MIVAN, Thyssen and Cantilever. Each of these firms offers its own specialized products. Some can even provide a very wide range of services including design support or tender estimating advice. As the use of innovative building methods gains more attention from various sectors in the community, advanced formwork systems will become more widely adopted. The input through research and development by the well-established formwork manufacturers is no doubt a contributing factor. (Photo 12)
Photo 11a – gantry form used in the Siu Hong Station of West Rail projects

Photo 11b – the gantry form as seen from the side, with the suspended slab soffit clearly shown
3. **Technical considerations when using formwork**

The selection and application of formwork, particularly for large-scaled and complex projects, depend on the following factors:

### 3.1 Design-related factors

3.1.1 **The shape of the building**

Simple block-shaped buildings are much easier to construct than buildings in awkward shapes, such as projects with curved, inclined, stepped, undefined or sculptured features. As a general rule, awkwardly shaped buildings can be more easily dealt with by using more traditional, labour-intensive formwork systems for their better adaptability.

3.1.2 **Design of the external wall**

Some buildings may have many architectural features on the building exterior such as fins or ribs, sunshading blades, planter boxes,
rebate windows or hoods for air-conditioner units. These may limit the choice of system-type formwork due to features that interrupt with the casting process.

3.1.3 Internal layout
Some buildings may have very simple layouts with few in-situ walls and floor plates framed with regularly spaced columns, as seen in many commercial and office buildings. However, some developments feature very complicated load-bearing internal walls that can make the casting process difficult.

3.1.4 Structural forms
Like internal layout, the structural form of buildings also affects the formwork options. For example, buildings with a structural core in the form of a vertical shaft limit the use of other formwork systems other than those of a self-climbing nature. Buildings in flat slab design make table forms or flying forms the most obvious choice. For buildings with regularly arranged shear wall designs, the best selection is large-panel type steel forms or other types of gang forms.

3.1.5 Consistency in building dimensions
Some buildings may have non-standardised dimensions due to the architectural design and layout or to fulfill other structural requirements. These include the regular reduction of sizes for beams, columns and walls in high-rise buildings as the structure ascends. Some formwork systems, like the climb form or steel form, may be quite difficult to use in such situations, for the frequent adjustments of the form to meet the changes in dimensions may eventually incur extra cost and time.
3.1.6  **Headroom**
Higher headroom increases the amount of falsework required and can also create accessibility and safety problems. It can also make the erection of formwork, ensuring formwork stability and the placing of concrete more difficult. Working headrooms of more than five metres are frequently encountered in buildings with transfer structures (Photo 12), entrance foyers (Photo 13), atriums inside shopping malls and many other functional, institutional and public buildings.

3.1.7  **Building span**
Large building spans also create problems similar to those with high headroom situations. In addition, long-span structures generally have larger beam sections, heavier reinforcement provisions, or accompanying post-tension works (Photo 14). This will further complicate the formwork’s design and erection process.

![Photo 12](image1.png) – the transfer structure practically subdivides the construction into two work fronts: the podium and superstructure (Park Avenue)

![Photo 13](image2.png) – very high headroom required the provision of complicated falsework (Belcher Garden project)
3.1.8  **Repetitive nature**  
High-rise block-shaped structures usually require highly repetitive cycles and this is favourable to the use of formwork. However, the degree of repetition in building with very large construction area like a podium or underground structures such as basements is limited and the use of formwork, as an expensive resource, becomes very critical.

3.1.9  **Surfaces finishes**  
Fair-faced concrete demands very high quality formwork in terms of surface treatment of the panels, tightness of the formwork joints and in dimensional accuracy. Requirements are slightly relaxed where the concrete surface is to be finished at a later stage.

Photo 14 – heavily reinforced beams with post-tensioning design (Terminal Building, new HK International airport)  

Photo 15a – exceptionally large-sized project as in the International Airport of Hong Kong at Chek Lap Kok
3.2 Construction-related factors

3.2.1 Complexity of the built environment

Exceptionally small or large sites (Photo 15a & 15b), sloped (Photo 16) or very crowded sites (Photo 17), proximity to sensitive structures, sites where other major activities are underway (Photo 18), or sites with many physical or contractual restrictions will increase the difficulty of working with formwork. There is no specific solution to improve the situation in general and problems are tackled according to individual circumstances.
3.2.2 Speed of work

When working with buildings with large construction areas and horizontal spread, projects can be expedited by the introduction of additional sets of formwork, to create more independent work fronts. This will, of course, increase the cost of production. For high-rise buildings, increasing the number of formwork used cannot always solve the question of speed, for the critical path still depends on the floor cycle. However, a properly selected, designed and arranged formwork system will increase work efficacy for each typical cycle. In some cases, adding half or a full set of formwork, especially for the floor forms, may help to speed up the cycle as the additional set can provide more flexibility when the form is struck at an earlier time.

Photo 17 – working in very crowded site within urban environment (commercial building in Central, Hong Kong)

Photo 18 – a wide variety of major construction activities taking place within a very large site (Festival Walk)
3.2.3 Re-use of formwork
The re-use for traditional timber formwork is usually limited due to the durability of the plywood sheeting. The optimum number of times of timber form can be used is usually 12 to 14. Thus, it is still sufficiently economical to use timber formwork for high-rise buildings at heights in accordance to the multiple of the usual re-used times. Although the metal form can be re-used many times, the high initial cost of providing the form often discourages its selection, especially when there is no need to re-use them too many times, for example in a low-rise development. A careful balance between cost, speed, performance and the quality of output should be properly considered when making the selection.

3.2.4 Construction planning and arrangement
Constructing planning such as the phasing or sectioning arrangement, integration of the structure, site layout and set-up arrangements or hoisting provisions and concrete placing facilities are influencing factors when considering formwork selection and application.

3.2.5 Area or volume of cast per pour
The optimum volume of cast per pour depends on the types of formwork used, the particular elements of structure to be placed, the actual scale of work, and different levels of provisions of plant facilities. Usually a volume of concrete ranging from 60 to 200 cubic metres per pour can be comfortably handled in most site environments. It also depends on whether the concrete to be placed is for the vertical elements only or also includes the beams and slabs, as a means of saving an additional phase in the overall work cycle.

3.2.6 Involvement of other construction techniques
The applications of tensioning and prefabrication techniques are often involved in the construction of high-rise buildings. This may
create certain impacts on the use of formwork, especially where precast elements are to be incorporated during the casting process (Photo 19). Allowances should be made for additional provision of temporary supports or slot spaces and boxing out positions in the formwork for the precast elements, or extra working space for placing stressing tendons and onward jacking.

3.2.7 Dependence of work
Many factors should be considered before employment of a construction plan and the selection of the right formwork system. These include considerations of whether there will be lifting appliances provided for the erection of formwork; whether these appliances will be able to access the work spot to assist in the operation as the structural works proceed; whether any special equipment will be required for striking the forms; and how the removed formwork panels can be transported to other spot to continue work.

3.2.8 Provision of construction joints
Sometimes a large number of construction joints is inevitable in a large structure because of the subdivision of works into effectively workable sizes. The provision of construction joints can challenge the output and affect the quality of the concrete (Photo 20a & b). Careful selection should be made to ensure a particular formwork system can satisfactorily allow such arrangements.
Photo 19 – large-sectioned beam with slot position for precast secondary member (podium, Hung Hom Station)
Photo 20a & b – location in structure where complicated construction joints are to be provided
3.2.9 **Accessibility to work**

During the course of construction, accessibility problems may be created through segregation, temporary discontinuation, or blocking of the layout by the partially completed building (Photo 21a & b). Or, in cases constructing a shaft-type core wall is constructed in an advanced phase, the shaft may stand independently for a long period of time before it is connected to the horizontal elements. Arrangements for access to work places should be properly arranged when carrying out construction planning.

Photo 21a, & b – situations where the access of a large site is temporary blocked by the partially completed structure (Metropolitan project in Hung Hum on the left, and the Nina Plaza project on the right)
3.2.10 Feasibility of introducing alternative designs

Under the traditional design and construction detached procurement system, architects often design a building which is not suitable for use of more advanced and efficient formwork systems. It is quite common for builders to submit alternative design proposals to clients for consideration with minor structural or architectural amendments so that more effective formwork methods can be applied. Very often, the cost benefit derived is shared between the builder and the client in order to achieve a win-win situation.

4. Examples of application

Following are a number of recent construction case studies in Hong Kong for illustrating the use of formwork systems on unique projects.

4.1 Festival Walk – using traditional manual-type timber formwork

This project is built on a 21,000 sq m site. The development is a shopping mall and leisure center that comprises a four-level basement and a seven-level upper structure. Design and construction features include:

a) A 48 m-span skating rink constructed of eight in-situ cast and post-tensioned beams, supported on the sides by bearers (Photo 22).

b) The basement was constructed using the top-down approach.

c) A 40-m diameter circular ramp down into the basement was also constructed in the top-down manner (Photo 22a).

d) A number of large span structures up to 32m in length were cast in-situ; the majority were post-tensioned.

e) 3 atrium spaces, averaging 35m in span, and with 25m headroom (Photo 23).

f) Average headroom for each floor is about 4.5m.
Due to the specific functions of the building, the layout of the 160,000 sq m building has few repeatable elements, making the application of system formwork not feasible. As a result, traditional formwork with timber panels was employed throughout the project (Photo 24a, 24b & 24c). Since the overall building area is extremely large, the structure was subdivided into six main phases with further sub-sectioning in each phase. The main phases were constructed in a progressive and staggered manner both for the basement and the superstructure, each with a lapse of about one to two months. A large amount of construction jointing was provided during the construction, making the casting, coordination and quality assurance process fairly difficult (Photo 25).
Photo 23 – Atrium space within the Festival Walk forming a very splendorous mall interior

Photo 24a – timber form for the slab of the podium structure

Photo 24b & 24c - using of traditional timber formwork to construct the complex structure of Festival Walk

Photo 25 – complicated phasing and sectioning detail within the gigantic structure of Festival Walk
4.2 **Belcher’s Gardens Redevelopment** – using traditional manual-type timber form

The development is located on a sloping 24,000 sq m site. A 10-level podium structure, housing a carpark, shopping mall and recreational facilities, was built on top of the sloped site in order to provide a terrace to seat the residential towers. The upper and lower levels of the slope have a difference of about 65 m. Six 48-storey residential towers are built on top of the podium, providing about 2,200 residential units each of about 80 sq m in size. To construct the podium on the formed slope, complicated falsework had to be erected, creating many elevated work positions that significantly retarded the progress of work. The huge size of the podium and the sophisticated site topography demanded very complicated phasing and sectioning arrangements (Photo 26).

For the superstructure, due to the irregularity in the layout, the incorporation of a lot of architectural features in the external envelope and the use of a large amount of short-span slabs and shear walls, manually-operated timber panel forms were again adopted (Photo 27). As most structural forms for high-rise residential buildings have similar designs, the Belcher’s Gardens redevelopment can be regarded as typical of these works in Hong Kong.
Photo 26 – complicated phasing and sectioning arrangement for the podium structure of the Belcher’s Garden

Photo 27 – traditional timber formwork employed for the construction of the residential towers in the Belcher’s Garden
Photo 27a – layout of the podium structure and the column and floor arrangement

Photo 27b – falsework for the casting of the bracing beams located under the transfer plate of each residential tower block
Other features related to the use of formwork

a) The span of the podium averaged 12m. Circular and squared section columns up to 3m x 3m in section are used (Photo 27a). For the floor system, a flat slab design was employed for the lower floors to increase headroom. A beam and slab system was used for upper floors.

b) Inclined bracing beams were used in the upper podium structure to stiffen the residential tower on top (Photo 27b).

c) A 3m deep transfer plate, tensioned and cast in 2 layer, was placed on top of the podium columns as support for the residential tower (Photo 27c & 27d).
4.3 **Lee Gardens Redevelopment** – Climb form for core, composite slab and structural steel outer frame

This is a 50-storey office building in the form of composite structure with the inner core constructed of reinforced concrete and an outer frame of structural steel. The RC core was constructed using VSL climb form, which is a self-lifting formwork system that uses hydraulic jacks to operation (Photo 28a). The panel shutters used for the walls were operated on track rails to allow opening and shutting actions during the erecting and striking processes. The shutters and rail tracks, together with the scaffold systems, were hung onto a steel gantry frame which further articulated to the jacks to lift the entire system (Photo 28b).

![Photo 28a – set-up of the climb form for the Lee Garden Hotel redevelopment project](image1)

![Photo 28b – detail showing the gantry, shutter panels and guide rail system of the climb form](image2)
Other features related to the use of formwork

a) The 4-level basement was constructed in complicated phases using top-down method with the old 2-level basement structure of the previous Lee Gardens Hotel carefully replaced during the process (Photo 29a). Traditional manually-operated timber forms were used for basement construction.

b) The basement portion of the core wall of the 50-storey office tower was constructed using traditional timber forms. The VSL climb form was erected after the completion of the ground floor slab and was used to cast the upper portion of the core wall up to the 50th floor (Photo 29b).

Photo 29a – the 4-level basement gradually replaced the old 2-level basement structure in complicated phases
c) The construction cycle for typical floor averaged at 4.5 days per floor. Expected delays occurred at several locations, including on floors with outrigger provisions on which a very complicated anchor steel frame was required for insertion into the core wall to connect the outriggers, as well as on floors where the size of the core wall was progressively reduced (Photo 29c).

4.4 Cheung Kong Center – Jump form system for core; composite slab and concrete-filled steel tube as the outer frame

Cheung Kong Center is a 62-storey office building featuring a composite structure similar to the Lee Gardens Redevelopment project but on a larger scale. Instead of using the climb form, this project employed a jump form system patented under the product name Cantilever (Photo 30a, b & c). Besides using the form to construct the core wall in an advanced phase with necessary provisions of starter bars for connection to the composite floor slab, the other difficult part of the formwork process was allowing placement of three sets of anchor frames inside the core for connection to 550-tonne outrigger frames at three prescribed levels (Photo 31a & b).
Other features related to the use of formwork

a) The entire core wall structure for the 62-storey office tower was constructed using a jump form system which was erected for the casting of the wall starting from the lowest basement level. This was made possible by the provision of a 37m diameter shaft for the purpose (the shaft was also used to facilitate the construction of the basement, Photo 32a & 32b).

b) The construction cycle for typical floor averaged 3 days per floor. Expected delays occurred at several locations similar to the problems encountered on the Lee Garden Redevelopment project.

Photo 30a – ascending of the core wall with the jump form in position
Photo 30b – close up seeing the jump form for the construction of the core wall
Photo 30c – detail of the jump form as seen on the working deck level

Photo 31a & b – the connection of the outrigger frame into the core wall structure
4.5 The Gateway II – Climb form for core and table form for slab

There are three towers in this project, each rising 38 storeys and housing offices and serviced apartments. The tower structures comprise a central core with 12 m-span RC columns placed to form the outer envelope and a post-tensioned flat slab system for floors and horizontal restraint. The core walls were constructed using the VSL climb form. Columns were built with gang forms and the slabs were cast using an aluminium-strutted flying form system (Photo 32a & 32b). The slabs were cast in two separate sections in a staggered manner with a lapse of two to three storeys (Photo 33). This arrangement has the flexibility of gaining one more work front so that the floor area can be split into smaller, easily-handled portions with better access for tensioning works (Photo 34). The drawback is that the integrity of the structure is broken and a number of construction joints were required in the structure. Besides, the number of sets of formwork to be provided and the strength development period of the concrete before tensioning can be applied had to be properly balanced in order to achieve the most efficient schedule.

Photo 32a – the flying form system employed in the Gateway project

Photo 32b – seeing the formwork arrangement for the floor system and the core wall
4.6 Harbourfront Landmark – Steel panel form for shear walls and table form for slab

This 72-storey residential development contains three residential towers on a 7,500 sq m site (Photo 35). The building structure consists of a series of shear walls to form the compartment units, centred with a core structure. A full steel form system was used for all the walls (Photo 36a). For the slabs, an aluminium-strutted flying form system was used for the majority of areas except for a small portion at the rear housing kitchens and minor lobbies where traditional timber/plywood formwork was used. The central cores were constructed in the form of a vertical shaft (Photo 36b). The inner structures such as the slabs for the lift lobbies, the lift walls and landings for the stairs were cast in-situ at a later phase (Photo 36c). The stair flights were prefabricated and erected at pre-arranged positions inside the core.
Though the construction concept looks quite typical and similar methods have been widely used in public housing development in Hong Kong, this project is in fact a pioneer among private development. This is especially notable considering the complicated external shape of the building. The project was not run under design and built contract, yet certain design alternatives were introduced. Within the relatively conservative culture of Hong Kong’s construction industry, this may serve as a prototype in the application of more innovative technologies in private sector building construction.

Photo 35 – external view of the semi-detached residential building towers

Photo 36a – the steel form for walls employed in the Landmark Waterfront project
The project comprises four 46-storey residential towers (Photo 37a). A full aluminium MIVAN formwork system was used in the construction (Photo 37b). Typical of designs for Hong Kong residential buildings, the structure includes a large number of shear walls forming the external walls, staircases and lift walls, as well as the majority of inner walls between apartments or other functional units. Beams serve as tie elements while external architectural features such as planter boxes and air-conditioner hoods are also incorporated into the design.

The first five typical floors took an average of 15 days each to complete. It then took about 8.5 days per cycle to complete each remaining storey. This is much too slow when compared to similar projects with floor cycles of five to six days. The problems seemed to come from the
large amount of walls to be formed, a complicated layout and other architectural features, as well as inconsistency in the sizes of major elements. As a result, labour input was unexpectedly high and caused significant delay to the works.

Other features related to the use of formwork:

a) Supporting column clusters were first constructed from ground to support the transfer plate structure, which was located about 20m from the existing ground level (Photo 38a & 38b).
b) The support steel frame was erected on top of the columns cluster as falsework for the construction and casting of the 2.8m thick transfer plates (Photo 38c).

c) The podium structure below the transfer plates was constructed afterward from the ground level at the same time with the superstructure of the residential towers (Photo 38d)

Photo 38a – the column clusters erected for supporting the transfer plate for the 4 residential tower blocks.

Photo 38b – detail of the column clusters, with the steel forms for the casting of the columns clearly observed.
5. **Application of Innovative Formwork Systems in Hong Kong**

Are the formwork systems employed in Hong Kong innovative? What is the future of more innovative formwork systems in the local construction industry?
According to studies in this area, innovative construction technologies have the following features in common:

a) Engage fewer resources to achieve the same output
b) Yield better performance when compared to traditional methods
c) Ability to cater for other associated works during the construction process in a more coordinated manner
d) Better adaptability to cope with variances and changes in the design
e) Achieve the task neatly and faster
f) Safer work processes
g) More environmental friendly

Some basic conditions must be met before innovative technologies can be applied, these include:

**External conditions** (on community level)

a) Readiness and flexibility of procurement formats for construction projects, in particular large and complex one.
b) Readiness of the related professions, which include the developers, architects, engineers, contractors, sub-contractors and suppliers.
c) Expectation of society in terms of quality, cost effectiveness, wiser and greener products and services etc.
d) Development of a mature market for the economical supply of new products and services.

**Internal conditions** (on institutional or corporate level)

a) Readiness for cultural reform in the search for excellence and quality performance, not just the adoption of window-dressing type exercise.
b) Development of better manpower with the required vision, experience, qualification and competence for technological and managerial advancement.

c) Development of the required support in terms of information technology, computer networking, equipment and other logistic support.

d) Readiness of the managerial structure to cope with new technology, market and other business environments.

The current situation in Hong Kong

The support of a very active economy over the past one or two decades has led to significant developments in the construction industry in terms of experience and mastering of the required managerial, construction or engineering skills for handling very large and complex projects. At the same time, the motivating factors highlighted above have created an eagerness and readiness within the industry to advance. From the building construction point of view, the use of better formwork systems is no doubt a very direct way for introducing innovative methods in the construction of buildings. Below are some motivating factors:

a) Formwork labour cost is so immense that any innovative system resulting in a labour cost reduction is highly tempting.

b) Fulfillment of fast track construction schedule provides fewer choices, one of which is to adopt more innovative formwork systems.

c) Traditional systems can hardly satisfy the tight quality standard that is required nowadays.

d) Similarly, traditional systems can hardly satisfy current safety and environmental standard.

e) The accumulation of experienced operators makes the application of more sophisticated formwork systems more reliable and economical.

f) Many developers view the application of innovative technology in the construction process as a positive image-building factor.
Advanced formwork systems are only part of the advanced technology equation. Quite a number of recent projects have already integrated the use of advanced formwork systems and prefabrication techniques with success. Examples can be found at the Harbourfront Landmark project in Hung Hom as previously highlighted. Other examples include the construction of most public houses (Harmony and Concord blocks, Photo 39a & 39b), staff quarters (in Tai Kok Tsui and Lai King, Photo 40a & 40b) for the Hong Kong Police Force, some private commercial and residential developments (Swire House Redevelopment located in Central, Photo 41a, b, c & d; Residential development in Stubbs Road, Photo 42a & 42b), or the depot building for Kowloon Motor Bus Ltd. at Lai Chi Kok (Photo 43a & 43b), these are projects that employed a large proportion of innovative elements in the construction.

Photo 39a – typical formwork and prefabrication arrangement for Harmony Block construction

Photo 39b – a very complicated combination in the construction of a new housing estate in Yau Tong area showing the podium, transfer plate and superstructure construction arrangement.
Photo 40a – similar construction concept using a significant amount of prefabrication for a staff quarter for the Police Force in Tai Kok Tsui

Photo 40b – detail of the formwork arrangement as seen on the deck level for another staff quarter project owned by the Police Force in Lai King area.
Photo 41a & b – detail of the climb form being used in the Swire House Redevelopment project
Photo 41c & d – formwork arrangement for the core wall and floor system. Note that the flying form for the floor is arranged in a smaller size for easy lifting and handling by a specially designed hoisting rack (on the left). This arrangement can relief the carnage time and allow the crane be used in other more critical work activities.
Photo 42a – set-up of the jump form system to construct a 60-storey residential tower block in Stubbs Road

Photo 42b – detail of the jack arrangement for the jump form as viewed on the deck level
Photo 43a & b – a more innovative approach is being adopted to construct the Kowloon Motor Bus depot structure making use of large amount of prefabrication design. Traditional formwork is being employed only for elements like the staircases walls, bus ramp and the administrative block structure.

Following are, in the author’s view, the potential and limiting factors of innovative technologies in the built environment of Hong Kong.

**Potentials**

a) The public’s expectation (government, developers, building users) are rising all the time.

b) More stringent regulations have been imposed to control the performance of the construction industries.

c) Accidents are costly, especially where human casualties are involved (both for the reasons of compensation, imaging and government records).

d) The development or importing of more advanced technology have become more common and market affordable.
e) Some other work systems and supporting logistics are becoming mature.

f) The industry is gradually accepting the production of higher performance buildings involving a more expensive resource input.

**Limits**

a) Insufficient research and development at most contracting firms or other supporting units.

b) Lack of working space on construction sites (both on site or other work areas off-site).

c) Training opportunity (including on-the-job training) is still limited for both the professionals and other workers.

d) No guarantee of a consistent market environment for the development and continual application of innovative technology in construction (learned skill and experience will lose eventually).

e) The extensive use of cross wall design especially in most residential buildings and small-scaled projects makes the use of more innovative formwork system less feasible.

f) The exceptionally large scale and complex nature of projects in terms of the site condition as well as structural and building design confine the application of more advanced and sophisticated formwork system.

The economic turn down in Hong Kong also means that neither developers and contractors have the capital to invest in more innovative technologies. Similarly, the shrinking of the property market has created extremely keen competition that has discouraged the application of initially more costly innovative technology in construction. This also applies to the supplier markets through which innovative products are often introduced.
Without a guarantee of a consistent market environment in the development and continual application of innovative technology, learned skill and experience cannot be easily accumulated. This can, to a certain extent, also explain why the use of structural steel in construction as a more innovative method of construction has not been adapted by local practitioners even though it is popular in Japan or other developed countries.

It is a pity that Hong Kong’s construction industry may miss the chance to enhance itself in the application of more advanced and innovative technologies due to the global economic downturn. When the recovery comes, it will unavoidable take several years to build up the momentum for innovation. In the meantime, the industry or individual corporations may consider for the following measures:

a) Explore ways to streamline and re-engineer the work structure on both the industrial and corporate levels.

b) Invest steadily in the human resources development and to train up more competent and high quality staff with the required attitude and readiness to work in the new environment.

c) Invest steadily in the research and development of technologies that are particularly suitable for the built environment of Hong Kong. The “Integer” Project sponsored by Hong Kong Housing Authority, China Light & Power, Gammon and Swire Properties, is a very good recent example.

d) Strengthen the linkages among government departments, developers, consultants and contractor firms in the promotion, development, cooperation and implementation of more innovative projects.

e) Government or other institutions may consider providing funding to support research and development for the exploration, recommendation or setting up of guidelines and standards in the application of newer technology and work systems in construction.
6. Conclusion

The selected cases in Section 4 illustrate the use of the major formwork systems in various common construction scenarios in Hong Kong. The intention of this paper is not to provide a detailed comparison or explain the technical features of any individual formwork system in depth. Instead, it aims to show the conditions and constraints governing the use of suitable formwork systems under typical local circumstances. There is no simple, ready-available solution for the use of formwork for complex buildings, especially when many Hong Kong projects are run in the fast-track manner.

The local industry has for a long time lacked the motivation to introduce highly innovative building methods due to a lot of understandable reasons. These include short-sightedness on the part of both developers and the contractors regarding investment in research and development, an extremely severe competitive environment based on lowest-bid arrangements, very high labour costs and the relatively conservative culture within the related professions and industries.

The use of formwork in construction occupies a critical place in the technological improvement process. Yet, in this regard, the pace of change in Hong Kong has been rather slow. The economic downturn and restructuring and rising environmental concern in particular have provided the motivation to seek more efficient and higher quality construction systems. These adjustments can be as simple as the training and attitude of the work team from the management down to individual labourers, their sense of loyalty and belonging, housekeeping issues on site, or safety and quality consciousness. These issues share equal importance in the introduction of advanced technologies as a whole. However, slow adoption of these principles shows Hong Kong's construction industry still has quite a long journey to travel.
References


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