CHALLENGES IN THE PROCUREMENT AND COSTING OF MODULAR INTEGRATED CONSTRUCTION IN HONG KONG

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ABSTRACT

The article shares an experience in one of the pioneering projects in Hong Kong adopting "Modular Integrated Construction ("MiC")" method from a quantity surveying aspect regarding procurement and cost. The concept of "MiC" is to have the building to be constructed as "factory assembly followed by on-site installation", in other words, independent prefabricated modules (including decoration works, fitting out and basic building services works) will be completed in factories and then being transported to construction sites for installation. It took about two years for the team to turn a "MiC" idea into an "Intent" solution at the early design stage. In consideration of the present building regulation and ensuring fair competition in the returned biddings, it is a big challenge as a quantity surveyor in preparation of the cost budget, tender documents and the contract administration after the award when no such similar project has been done in Hong Kong. Besides sharing some of the technical problems encountered in incorporating the "MiC" idea, this paper will share how to handle the challenge in the following: -

- Introduction
- Background of Project
- Securing a competitive tender price;
- Assessing the technical capability of the tenderer;
- Contractual relationship with "MiC" specialist;
- Shortened contract period;
- Implementation of off-site works payment;
- Off-site works quality check;
- Costing of "MiC" in Hong Kong;
- Conclusions.

This project was prepared based on achieving the target of "MiC" method which can raise productivity, shorten construction time, enhance construction safety and improve quality of the works. This paper will analyze the cost implication for adopting the advance "MiC" method compared with the traditional cast-in-situ construction method.

INTRODUCTION

Hong Kong is a developed city with a serious problem in labor shortage, particularly in the construction industry which results in a surge construction cost. "Modular Integrated Construction" ("MiC"), which is a modern method of building construction, refers to a construction whereby free-standing integrated modules (completed with finishes, fixtures and fittings) are manufactured in a prefabrication factory and then being transported to site for installation in a building[1]. "MiC" is the same as "Modular construction" in United Kingdom and Prefabricated Prefinished Volumetric Construction ("PPVC") in Singapore.

Based on the experience of the United Kingdom, it is concluded that with the volumetric construction, the construction programme can be cut by 60%, leading to substantial saving in time-related costs such as site supervision, insurance, security, waste disposal and temporary offices and also the finance charges to the project cost. The environment also benefits from having the construction waste reduced by up to 80% as it is easier to work with prevision in a factory-controlled environment, as well as to protect the works from materials damage. Logistically, for a developed city, all the raw materials are delivered to the off-site factory located closer to the source of material, deliveries of raw materials to the construction site are thus reduced by 70%; and thus, the carbon footprint is reduced. The offsite factory production environment enhances the consistency of process and drives up the quality of the Works. Projects with volumetric modules have demonstrated 80% fewer defects and dramatically reduced snagging phases compared with traditionally cast-in-situ constructed buildings.

It was recognized that the project was completed in a shorter time frame, however, as per the experience in Singapore which started the use of "PPVC" in Jun 2015, for their first "PPVC" pilot project at the NTU hostel, it resulted in 18% higher in costs compared with traditional cast-in-situ method. Luckily, in their subsequent cases, it proved that the use of "PPVC" method in Changi Crowne Plaza Hotel extension project could help to shave off construction time by approximately 17%, and reduced manpower on site by a staggering 40%, albeit at a 10-15% cost premium. The use of "PPVC" in Brownstone Executive Condominium (the first large-scale residential project to adopt the technology) is expected to improve productivity by up to 40%, which is about 55,000 man-days.

Hong Kong is well-known as a high construction cost city in the Asia Pacific and amongst the cities worldwide. As stipulated in the Hong Kong Government Policy Agenda 2017, the Development Bureau of the Hong Kong Government is now promoting and leading the adoption of Modular Integrated Construction in the construction industry. By adopting the concept of "factory assembly followed by on-site installation" and the mode of manufacturing, labor intensive processes can be accomplished in an off-site prefabrication yard to enhance the productivity and cost-effectiveness. With the successful track record in United Kingdom and Singapore, it is also believed that "MiC" can raise productivity, shorten construction time, enhance construction safety and improve quality of the works. Since every city has its own problems to be tackled for the implementation of a new construction method, and our project being one of the pioneering projects in Hong Kong, we have spent about one and a half year in the tender preparation and the coordination with the Government Departments to convert the "concept" into a design for the tenderer to bid for the Works. It took years to confirm the land grant of our project to pass through Government Departments such as district councils, town planning board, lands departments and so. Therefore, the design development in "MiC" project was perfectly matched with this land grant application procedure period.

[1] Definition of "MiC" extracted from Practice Note for Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers (PNAP) ADV-36 issued by Buildings Department, HKSAR.

BACKGROUND OF PROJECT

Hong Kong is a well-developed city, so land sources in the Urban area, particularly in the Hong Kong Island side, are very limited. The location of our project is at the southern part of the Hong Kong Island at the Wong Chuk Hang, nearby the famous Ocean Park, which is currently a hill side before the construction.

Picture 1: Nearby environment of the project

The project consists the construction of two 17 floors each student residential hostel towers on top of a 3-level podium for the University of Hong Kong. The notional floor area is 14,277m2 and the construction floor area is 27,937m2. The typical floors of the tower portion will adopt the hybrid modular units while the tower core, the transfer plate, podium, sub-structural works and the foundation works will be based on the traditional cast-in-situ construction method.

Figure 1: Identification of the "MiC" modules of the project

BACKGROUND OF PROJECT (CONT'D)

In order to suit for the "MiC" method, the layout of the tower and the core have been adjusted to ensure that it can match with the "MiC" modules divisions. The revised layout shown in figure 3 is to promote the typical and repetitive modules nature and the enlarged central portion design helps to develop a more rigid form of the building tower which facilitates the structural calculation of the "MiC" units.

Figure 2: Original Typical Layout Approved by Buildings Department

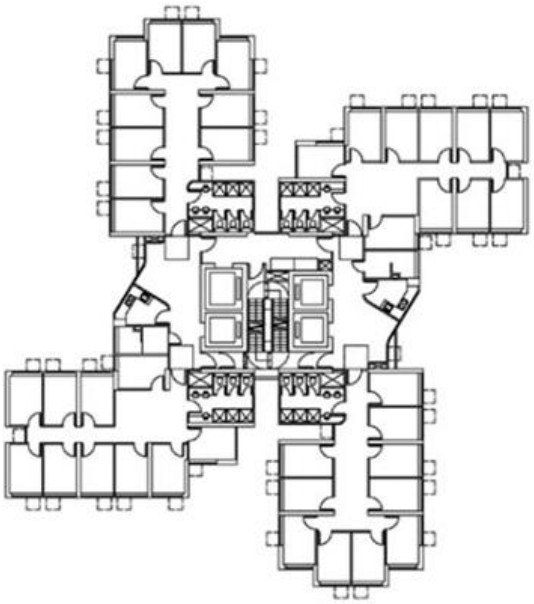
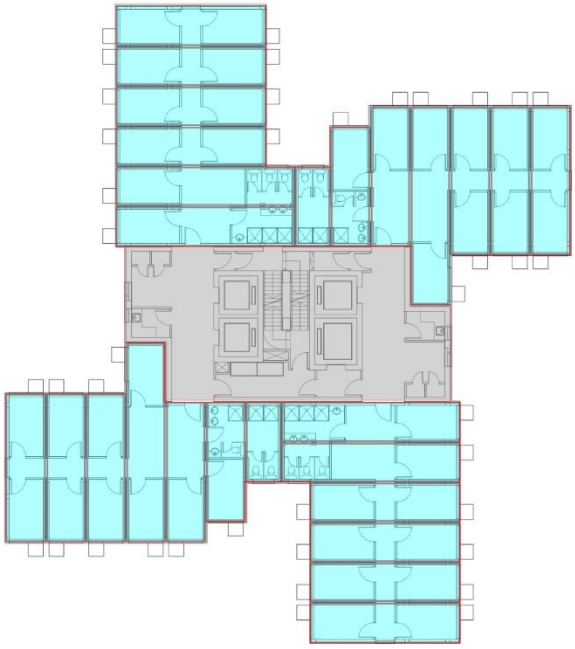


Figure 3: Proposed "MiC-Ready" Layout



This paper will mainly focus in the procurement approach for a government sub-vented project and the cost effect in adopting the use of Modular Integrated Construction method in Hong Kong.

SECURING A COMPETITIVE TENDER PRICE

This is a University student hostel project with Hong Kong Government subsidies which is known as a sub-vented project; In a sub-vented project, the Government will be responsible for most of the project cost and the University have to be responsible for the remaining portion. Usually, the funding from the Government has a capped sum which will be trimmed down should the awarded contract sum be less than the budget allowance. For the increase of the flexibility of the funding arrangement, the Government has relaxed the requirement for the possible reduction of funding for a lower than expected returned tender price. However, If the awarded contract sum be greater than the budget allowance, the responsibility in topping up the exceeded sum relies on the University. Unlike a private developer who is considered financially strong, the importance in securing a competitive tender price to the University is of utmost importance.

The tender for this type of project in Hong Kong is most likely tendered out in one whole package including the site formation works, excavation and lateral support works, foundations works, super-structure works, fitting out works, building services works and the external works. The tenderers must price all these works, i.e. no nominated sub-contracts nor direct contracts will be separately tendered. In this way, the funding arrangement can be secured before site formation works is carried out and the University has a lower financial risk if subsequent top up of fund is required after the actual Works has been started. The procurement method for this project is mainly based on Bills of Quantities with the building services based on Specifications and Drawings and the “MiC” unit is based on Design and Build. Since the value of “MiC” units takes about 40% of the total construction cost excluding Preliminaries and Contingency allowance, it is necessary to secure the “MiC” unit pricing in the competitive returned tender. The design team has developed a “MiC-Ready” design for the Building Department’s approval to ensure more “MiC” specialists to team up the main contractors in bidding. With this workable “MiC-Ready” design, the tenderer can submit a solid bid for the Works as modification of the “MiC” works mainly depends on the the “MiC” specialist’s own design deviation and the connection details only. This helps the “MiC” specialist to reduce the risk from the statutory requirements, particularly when as one of the “MiC” pioneering projects in Hong Kong, it takes time for the Government to establish a standard for approval as well.

ASSESSING THE TECHNICAL CAPABILITY OF THE TENDERER

"MiC" is an advance construction method in Hong Kong and there is no show case before; thus it is considered that a "MiC" specialist sub-contractor with high rise hostel experience in our neighborhood country works under the Main Contractor will be the most beneficial to the project. The technical capability of the tenderers' team is considered as a critical criterion for the selection of the tender. The returned tender will be assessed in both the technical and commercial aspects. Each tenderer has submitted the tender under two separated envelops and the commercial envelop of the tenderer can be opened only if the tenderers have passed the technical assessment.

Assessment of the tender in technical section comprises of two stages with the assessment carried out by the Tender Assessment Panel:

Stage I Screening - the tenders will be vetted against a set of Minimum Requirements;

Stage II Marking - the tenders will be assessed based on the marking criteria set out in the tender.

The Tenderer's submission must satisfy all the Minimum Requirements listed below for passing the Stage I – Screening:

- Being an Approved Contractor for Public Works for the Category of Buildings in Group C and will team up with the Approved Specialist Contractor for Public Works for the Category of Land Piling in Group II
- Confirmation of compliance with the Requirements on Submission of the Contractor's Modular Integrated Construction ("MiC") Proposal
- Submission of the Contractor's Modular Integrated Construction ("MiC") Proposal

If the Tenderers' submissions do not satisfy any one of the Minimum Requirements above, their tender(s) shall be treated as non-conforming tender(s) and shall not be considered further. Only those tenderers who satisfy all the requirements therein will be assessed at Stage II – Marking.

The tenders have been assessed based on the following attributes:

1. Tenderer's experience such as the number and the contract value of building contracts; the number of similar nature and complexity building contracts; experience of the teamed-up "MiC" specialist sub-contractor;
2. Tenderer's Past Performance such as workmanship in the past project reference; proof in meeting the progress of the past projects; site safety record; environmental control measures; attitude to claims; record against convictions;
3. Tenderer's Technical Resources such as details on organization of project team and manpower resource schedule committed for this Contract; experience and qualification of Core Personnel for Main Contractor; experience and qualification of Core Personnel for "MiC" sub-contractor; proposal to manage the Mechanical, Electrical and Plumbing (MEP) sub-contractors and "MiC" sub-contractor for timely delivery of project;

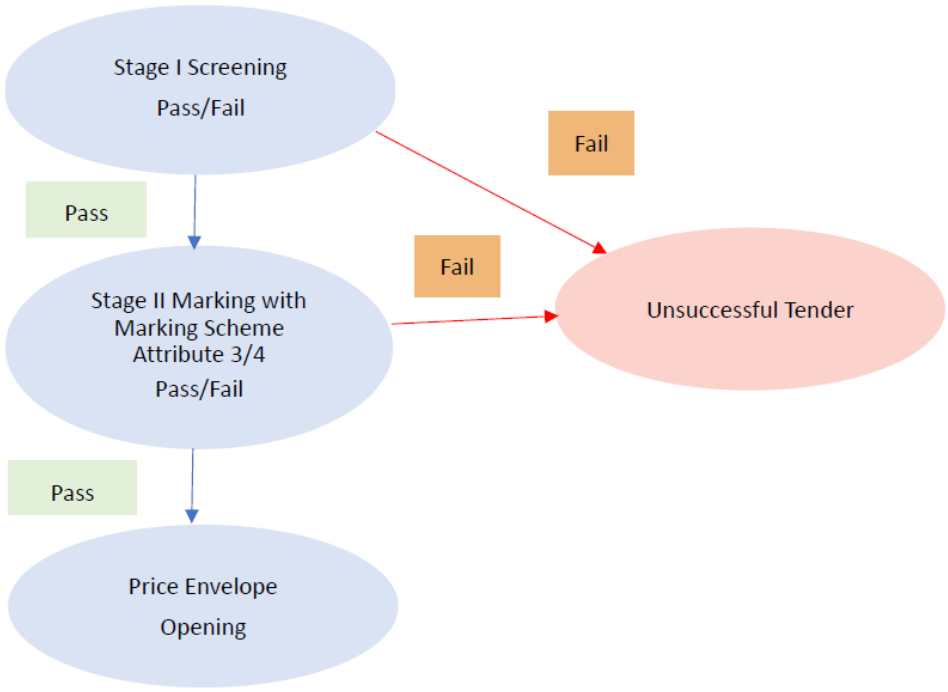
ASSESSING THE TECHNICAL CAPABILITY OF THE TENDERER (CONT'D)

The tenders have been assessed based on the following attributes: (Cont'd)

4. Tenderer's Technical & Design Proposals such as reasonableness in programming; proposed site layout plans showing site planning for critical activities and method statement and construction sequence/methodology to meet the programme; proposed contract period; site coordination; Project-specific quality control plan; project-specific safety policy and site safety plan, health and welfare plan; project-specific environmental management plan and waste management plan; Main Contractor's "MiC" proposal;

For Attributes 3 and 4 above, it is necessary for the tenderer to pass the passing marks of the respective attribute, then, the price envelope for these tenderers can be opened. The technical assessment procedure can be illustrated by Diagram 1.

Diagram 1: Technical Assessment Procedure



The respective weights for price and technical score are 60:40. The overall score for each conforming tender is determined according to the formula below. Normally, the tender with the highest overall score would be recommended for acceptance subject to the requirement that the Employer is satisfied that the recommended tenderer is fully (including technically, commercially and financially) capable of undertaking the contract.

$$60 \times \frac{\text{The lowest tender price among those conforming tenders}}{\text{The tender price}} + 40 \times \frac{\text{The technical score}}{\text{The highest technical score among those conforming tenders}}$$

ASSESSING THE TECHNICAL CAPABILITY OF THE TENDERER (CONT'D)

In consideration of the appropriate ratio in the technical score and the pricing score, several scenarios have been reviewed. Based on the anticipated tendered sum of about HK$1.1Billion, i.e. about USD$141.3Million, one technical mark in different scenarios account differently in monetary term: -

Technical score to Pricing score Ratio	30:70	40:60	50:50	60:40
One technical mark equivalent to how much	HK$8M (≈ US$1.03M)	HK$10M (≈ US$1.29M)	HK$15M (≈ US$1.93M)	HK$20M (≈ US$2.57M)

Most of the technical and fee assessed government projects in Hong Kong are based on the ratio of 40:60, which is considered as an acceptable range in financial consideration for the University and therefore, our project has also specified this weighting in tender analysis.

A further study on the financial risk of the tender has to be carried out based on the following criteria particularly when the combined scores of the tenderers are very close:-

a. net present value analysis;
b. front loading items considerations;
c. financial risk analysis, such as price allocation, etc.

Based on the above assessment, it is believed that a technically feasible and competitively priced tender with less financial risk can be chosen.

CONTRACTUAL RELATIONSHIP WITH "MiC" SPECIALIST

The design responsibility for the "MiC" units works relies on the Main Contractor. The Main Contractor can develop his "MiC" design based on the approved "MiC-Ready" design. The whole ideology is similar to the curtain wall specialist sub-contract work that the design development is highly relied on the specialist sub-contractor's input and each of the specialist may have their own system design particularly in the connection details.

As per Picture 2 shown, the Site is located at a hill side that an extensive site formation works, excavation and lateral support works, and foundation works will be involved. It is anticipated that it takes about two years to carry out this part of the Works. The Main Contractor can make use of this period to submit the amended "MiC" design to obtain approval from the relevant departments plus the construction of the required mock up in Hong Kong for obtaining approval from the design team and then can subsequently make use of the time in constructing the podium on site, which is anticipated to be about 5 months, to fabricate the approved modular units off-site. Therefore, it is believed that this extensive site formation requirement of the Site can allow sufficient time for the Main Contractor in "MiC" design submission and approval process.

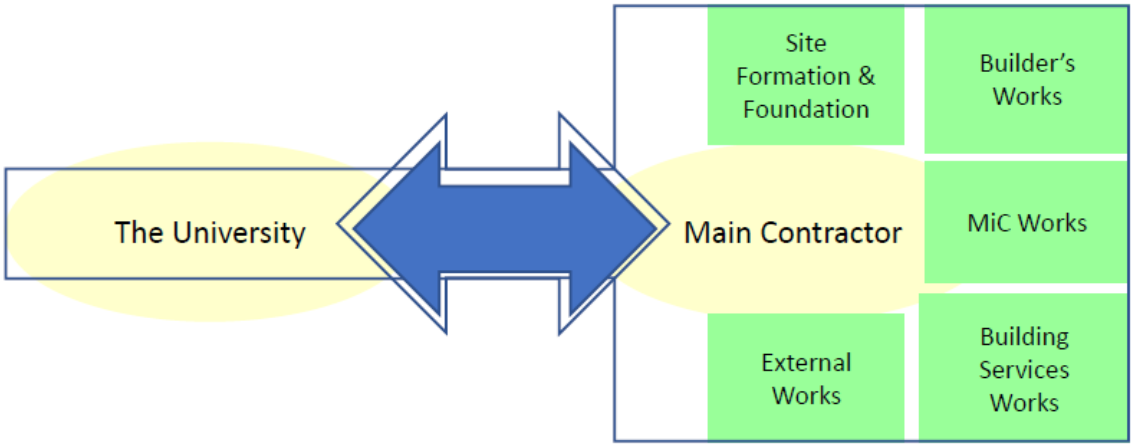
Picture 2: Close-up Condition of the Site before Construction

At the time of tendering for our projects, there were only four specialist sub-contractor obtained the Pre-accepted Modular Integrated Construction ("MiC") Systems / Components in Steel "MiC" systems of the Buildings Department. In this immature of MiC specialist work stage, we intend to increase the competitiveness of the tender amongst the tenderers. Therefore, in our project, the tenderer can team up with any "MiC" specialist sub-contractor to submit the tender. It is not restricted that the "MiC" specialist sub-contractor must be selected from any approval list, but the "MiC" specialist sub-contractor must have to obtain the Pre-accepted Modular Integrated Construction ("MiC") Systems / Components in the Buildings Department before the fabrication of the "MiC" units. On the other hand, the "MiC" specialist sub-contractors are allowed to submit their offers to various tenderers. It is proved that this procurement strategy is successful when there were eight tenderers to submit the tender, all of them have partnered with different "MiC" specialist sub-contractor. Thus, more competitive bids are returned.

CONTRATUAL RELATIONSHIP WITH "MiC" SPECIALIST (CONT'D)

It is believed that for a new construction method to be imposed, if the project team and the construction team work together as a partner to solve all the technical problem, there will be a higher chance of success in both technical and financial aspects.

Diagram 2: Contractual Relationship between the University and the Main Contractor



The Main Contractor and their domestic sub-contractors, "MiC" specialist sub-contractor, can further develop their design based on a MiC-Ready" design, which has already been approved by the Buildings Department. It helps to eliminate a lot of uncertainty in the construction aspect and it's easier for the "MiC" Specialist to develop the "MiC" units compatible to their own product. The backup plan is that they have to follow the approved "MiC" ready design to carry out the Works. The University have only one contractual link with the Main Contractor with no nominated sub-contractor nor nominated supplier. The Main Contractor have no excuse for any delay which may be caused by their own domestic sub-contractors including the "MiC" specialist sub-contractor.

Besides the Main Contractor's "MiC" specialist sub-contractor, under the Main Contractor's "MiC" team, they have their "MiC" manager to coordinate with their own design team and planning team, off-site factory supervision, quality assurance and quality checking team and on-site installation team. The Main Contractor are obliged to employ an independent "MiC" consultant team as well to line up with the "MiC" design submission process, the off-site fabrication and on-site installation process to enforce the Main Contractor's capability in the statutory submission and the coordination works in "MiC" production to minimize the potential risks. Since there is only one single contractual link between the University and the Main Contractor, the close coordination between the Main Contractor and the "MiC" specialist sub-contractor is crucial. As reflected in their tender submission, it shows that the Main Contractor are highly aware of the importance in such coordination works and thus have allowed significate resources in this part of the Works. In the technical assessment, the Main Contractor need to show their competence in the off-site factory supervision, quality assurance and allowance for the project team in the quality checking to ensure the requirements achieved.

SHORTENED CONTRACT PERIOD

The original contract period specified in the tender documents is 1530 calendar days. The tenderer can submit their proposed contract period but the same must be shorter than 1530 calendar days. Six out of eight tenderers have submitted their proposed contract period; ranges from 1252 to 1500 calendar days; i.e. 30 to 278 shortened calendar days in contract period. As it takes about 2 years for the site formation works, excavation and lateral support works, and foundation works and a further 5 months for the podium works, it is anticipated that under the original planning, it should be about 660 calendar days allowed for the remaining works including the tower portion including the obtaining of the occupation permit process. In view of the proposed shortened contract period by the tenderer, the percentage of time saving in using "MiC" method based on overall contract period is ranged from 2% to 18% and if in consideration of the works for the tower portions only, the saving is ranged from 5% to 42%. In addition, according to the technical analysis regarding the reasonableness of the proposed contract period, it is found that taking 1320 to 1360 calendar days to complete the Works (i.e. 161 to 210 shortened calendar days in contract period) are considered as reasonable time and thus the reasonable percentage of time saving in using "MiC" method based on overall contract period and based on the works for the tower portions only are adjusted to the range from 11% to 14% and from 24% to 32% respectively. The proposed time saving in contract period ties with the research figure of about 15% to 50% time saving in construction done by the University of Hong Kong based on the analysis from the literature review and international case studies in the Strategy Paper Rethinking Hong Kong Construction: Modularization for Modernization.

It shows that half of tenderers are quite conservative in the proposed time saving in contract period by adopting "MiC" method as it can be reflected by their proposals of the contract period saving are less than one and a half month or even none in their submissions. These tenderers are found to be those comparatively small in scale contractors and some of their MiC Specialist Sub-contract's experience are mainly in precast concrete works only. Besides, the number of modules and the type of "MiC" units proposed by the tenderer are also considered as the major factors in affecting the programme. As per one of the tenderer's proposal, they have adopted a hybrid system but involving more concrete works on site. Since the weight of their "MiC" unit is heavier, the smaller size per each module is required for uplifting purpose. In other words, more on-site uplifting works and also the connection works will be involved. All these lead to a less efficient on-site installation, i.e. less saving in their proposed contract period.

The shortened proposed contract period for the "MiC" works compared wtih the traditional cast in-situ concrete method mainly depends on the following factors:-

a. The design for fabrication and production of "MiC" units off-site must be confirmed at the early stage of the project;
b. The detailed delivery logistic planning for the "MiC" units from fabrication factory to Site;
c. The efficient checking and monitoring system to ensure the quality of the "MiC" units; and
d. The site planning including the uplifting facilities/method and the "MiC" units installation sequence planning.

For item (a) above, once the Employer's confirmation in the design is obtained, it highly depends on the reliability of the "MiC" Specialist Sub-contractor's productivity of the "MiC" products. The Main Contractor's teams mainly can supervise the workmanship, monitoring and checking the quality of the "MiC" units. It is necessary to ensure that only those "MiC" units passed the quality check can be delivered to the Site to avoid any defective product. It is also believed that under a controlled factory environment, the quality of the workmanship and product can be assured. It will then further discussed below for the measures to achieve the time saving target as per the other three factors

mentioned above, i.e. items (b) to (d).

SHORTENED CONTRACT PERIOD (CONT'D)

Since the factory production of the "MiC" units are in various parts of the Mainland China; most of the manufacture factories are in Guangdong area and a few are in the northern part of the Mainland China. Hong Kong is located at the southern part of the Guangdong Province, the closer the "MiC" factory it is, the lower the risk in transportation; and also the more in the carbon footprint reduction. There are two ways of transportation means for delivery of the "MiC" units from the factory to Hong Kong. One way is by land transportation while the other way is by shipment. More "MiC" units will be delivered in one goal by shipment and a temporary floating log is required for parking the "MiC" units; however, should there be any unexpectedly weather conditions during the sea ride, it may expose a higher risk in damage or lost of the "MiC" units. It is believed to have a better control of the sequence in delivery and installation by land transportation, however, there are still two major concerns: -

a. the "MiC" units may be held up when there is any delay in clearing mainland custom process and if there is any reclaim of taxes refund for imported materials, the delay may be even longer; and
b. the delivery of "MiC" units may not be able to catch up with the site installation progress that there may be a risk in affecting the programme.

Since the delivery and installation sequence of the "MiC" units are crucial for the projects to meet the target time saving, the following methods have been considered in the project management:-

a. a buffer storage of "MiC" units at the northern side of Hong Kong, where provides cheaper and spacious area, as a transit besides direct delivery of the "MiC" units from the factory to the Site; In Hong Kong, the road is very congested and narrow, to avoid the "MiC" units being held up by the traffic, contingency plan of items (b) and (c) below are required;
b. temporary holding area nearby the Site so as a back up plan if the "MiC" units delivered from the buffer storage or the direct delivery of "MiC" units from the factory to Site cannot meet the installation schedule; and
c. a back-up storage yard at another location is planned to minimize the traffic risk as well.

The checking and monitoring system such as the Radio-Frequency identification device (RFID) and the Building Information Management System (BIM) have to be implemented to track the "MiC" units from fabrication, transportation logistics and delivery to the Site and to ensure that the "MiC" units being installed at the exact locations as planned.

The site planning such as allowing two tower cranes, i.e. one tower crane for one tower, for our project to optimize the lifting and hoisting arrangement; the analysis of the tower crane size capacity with different jib length to match with the size of the module can help ensuring the most efficient way in lifting of materials on-site. The most important criterion is to make sure that the lifting capacity of the tower crane can meet the heaviest module requirements. As per the "windmill blade" shape of the two towers, it is anticipated a four-days cycle for both core construction and "MiC" installation with 16 numbers of "MiC" units to be installed per day. The sequence of the "MiC" installation works also needs to be carefully planned to utilize the lifting facilities to avoid any crash during the lifting process.

Should the above measures can be implemented successfully as planned, it is expected that the four days cycle per floor per two towers based on "MiC" method can be achieved and thus the overall construction period the committed shortened contract period can be met. For example, the general allowance for the traditional in-situ concrete is about seven days cycle per floor per tower. The construction period to be reduced will be 7 days x 19 floors x 2 towers minus 4 days x 19 floors = 190 days which is about 6 months in total.

IMPLEMENTATION OF OFF-SITE WORKS PAYMENT

The value of the "MiC" units is about 40% of the total construction cost excluding preliminaries and contingencies allowance. If the interim payment for the Works is only based on on-site evaluation as usual, the cash flow of the Main Contractor's team will be highly affected. An off-site works payment mechanism is allowed in the tender. The majority of Tenderer has proposed the payment terms for "MiC" units on the right hand side column according to the specified requirements in the tender:-

Payment Stage	Limitation on Range of Percentage in the Tender (%)	Proposed Percentage (%)
1) Upon submission of all "MiC" drawings regarding the different types of "MiC" units upto the Architect's satisfaction	Maximum 2% for Stage 1	2
2) Upon the approval of all "MiC" off-site mock-up and BIM model by the Architect	Maximum 5% for Stages 1 & 2	3
3) Upon the Architect's approval on manufacturing of "MiC" units in pre-fabrication manufactory	Maximum 30% for Stages 1, 2 & 3	25
4) Upon the completion of "MiC" units in pre-fabrication manufactory upto the Architect's satisfaction	Maximum 70% for Stages 1, 2, 3 & 4	40
5) Monthly progress payment on completion of installation of "MiC" units on Site	15 – 85	15
6) Upon issuance of Substantial Completion Certificate of the whole of the Works for the Main Contract	10	10
7) Upon expiration of the Defects Liability Period or upon the issuance of Defects Rectification Certificate for the Main Contract whichever is the later	5	5
Total Percentage of Payment for "MiC" Units Bill	100	100

Since there is no previous case to support the appropriate off-site works payment ratio in the local market, it is subject to the market response to propose the off-site payment terms for the "MiC" units with the limitation on the range that can be proposed by the Tenderer. It comes out to a result that majority of tenderers with various "MiC" specialists propose around 70% for off-site payment, i.e. from stages 1 to 4, which is believed to be the market trend. To minimize the University's exposed risk for off-site payment, the Main Contractor must fulfill the pre-requisite requirement for submitting the approved payment bond or cash security as per the Contract requirements. The bond or cash security for securing the off-site works payment must be in batch to tie in with the payment schedule. Such bond(s) or cash security(ies) can be released upon the corresponding part(s) of the "MiC" units have been properly installed on-site and evaluated and paid in the interim payment. The off-site works payment is allowed in this Contract to mitigate the financial burden of the Main Contractor to attain a more competitive bid from the tenderers and it seems that it is successful in this arrangement.

ENSURE OFF-SITE WORKS QUALITY CHECK

Upon confirmation of the design of the "MiC" units, the Main Contractor have to submit the material samples for the Architect's approval. Upon the finalization of the material approval of the "MiC" works, the Main Contractor have to construct a 2-storeys with 3 modules each level off-site mockup before factory fabrication to establish an acceptable standard. The standard of material established and recognized in Hong Kong is mainly based on the British standard and it is necessary to make sure that the installed materials off-site in the "MiC" units fully comply with the Specification requirements. Should the materials sourced from other location be used, the Main Contractor should obtain the recognized certificate to ensure that the equivalent standard of materials will be provided. The 2-storeys mockup is required to ensure the verticality in the connection of the "MiC" units as well.

The Ordinance in Hong Kong has the following requirements for the building services works installation to the "MiC" units:-

a. Electrical works shall be carried out by a registered electrical contractor (REC) who shall employ the registered electrical worker to carry out the electrical works;
b. Fire services works contractor shall ensure that the efficient working order of fire services installation and is expected to monitor, test and audit any fire services works in off-site factories;
c. Plumbing works shall be carried out under the instruction and supervision of a licensed plumber or registered plumbing worker;
d. Gas works shall be carried out by the gas installer and gas contractors,

the Main Contractor have to ensure that the relevant works are carried out and/or under the monitoring and checking by the appropriated registered trade workers so as to comply with the relevant Ordinances and all these requirements have been stated clearly in the tender documents. Under the tender, there is no restriction on which parts of the building services will be carried out by which specialist sub-contractors. It should be subject to the Main Contractor's own arrangement, and it must comply with the Ordinance in Hong Kong. The building services specialist sub-contractor were requested by the Main Contractor to submit two quotes for having the relevant parts of the works to be done by them and/or to be supervised by them as per the Ordinance required. It is found that most of the tenderers submitted are based on the building services specialist sub-contractor whom have their own direct labor in the Mainland China. It is expected that there will be more government support in adopting "MiC" in the construction industry to facilitate the approval process and the issuance of practice note for the "MiC" specialist to follow in all the future "MiC" projects.

The tenderers have submitted a quality assurance and quality checking plan for consideration. An independent quality checking team will be employed under the Main Contractor for checking the quality of "MiC" works off-site. The design team and a team of independent "MiC" checking specialists employed by the University will do the off-site works checking as well. The level and frequency of checking should be approved by the Architect. In general, it is expected that the structural parts, the architectural parts and the building services parts will be checked by the relevant parties before the works is/are being covered up to ensure that the approved materials will be used, and the workmanship is up to the required standard before delivery to the Site.

Another risk in damaging the "MiC" units is during the delivery from the factory to the temporary storage site/ the Site particularly during the uplifting of the "MiC" units. Therefore, it is necessary to have a detailed delivery, protection and uplifting plan to ensure that the properly checked "MiC" units will be installed on Site.

COSTING OF "MiC" IN HONG KONG

The Hong Kong University project is the third "MiC" development in Hong Kong. For all the tenderers that have passed the Stage I Screening and Stage II Marking, their submitted pricings are within the budget allowance. It is learnt from the first "PPVC" hostel project in Singapore that it was about 18% higher against the traditional cast-in-situ method. An analysis is carried out in comparing the construction cost based on traditional cast-in-situ method and the "MiC" method for this University project. It is found that the submitted tender price for the "MiC" method is lower if traditional cast-in-situ method was adopted for the current project which is about 7%. We have analyzed the major costing difference is the preliminaries and the buildings which accounts for about 13% and 11% saving respectively in these two different methods of construction. This University project is considered as a great success when it is believed that the market has learnt from the past "MiC" experience in other nearby countries with the similar nature, i.e. the returned pricing is considered with a reasonable risk allowance.

There are different types of module planned for the project and an analysis has been carried out to find the co-relation between the cost per meter square and the types of module. The cost per meter for the "MiC" units ranges from HK$15,000/m2 to HK$36,000/m2 (i.e. USD1,900/m2 to USD4,600/m2) with the following findings:-

a. For the same type of functional use, the bigger the size of the module, the lower the cost per meter that will be;
b. The cost per meter will be higher when more cladding surfaces are required;
c. The cost per meter for toilet is the highest amongst toilet, bedroom, communal lobby and corridor;
d. The cost per meter for bedroom is the second highest as more fixed furniture will be involved.

When the project was started with the implementation of "MiC" design concept in 2017, there was no cost reference in the market for having the "MiC" method in Hong Kong. Having checked with the "MiC" specialist, a figure of around HK$26,000/m2 has been worked out, i.e. USD3,350/m2, as a budget allowance for the construction of the "MiC" units. The tender returned for "MiC" unit is around HK$20,000/m2, i.e. USD2,600/m2 which is within the budget allowance.

The specialties of Hong Kong which affect the costing of the "MiC" the most are mainly the wind load requirements, the fire rated proof requirements of the compartment in design aspect and the fact that the buildings in Hong Kong are generally high-rise buildings. The requirements of the "MiC" units in the structural aspect is considered high compared with other countries in general. However, the favorable factors for Hong Kong adopting "MiC" method are that the factory location is close and thus the delivery cost from factory to Hong Kong is comparatively low and the labor cost in construction here is very high, and would be reduced if the "MiC" method is adopted. Therefore, in the long run, when the market becomes more mature with the advanced "MiC" method and with a balanced risk-allocated procurement approach in attracting a competitive bid, we expect the construction cost saving will be even more.

CONCLUSIONS

As per our neighboring country - Singapore's experience in adopting a similar modular construction method, the construction cost for their first "PPVC" modular construction hostel project is about 18% higher compared with the traditional cast-in-situ method. Being one of the pioneering projects adopting "MiC" modular construction in Hong Kong, initially we expect that the construction cost will be higher than the traditional cast-in-situ method as the "learning" cost of the industry. However, as the construction cost, particularly the labor cost, in Hong Kong is very high, it is also believed that the cost saving by adopting "MiC" should be more significant. In this project, having the balance between the quality, cost and time is emphasized the most. The procurement method allows the tenderer to propose or to have the flexibility of the followings:

a. The teaming up with their own "MiC" specialist sub-contractor;
b. Their own site formation, excavation and lateral support system and foundation system;
c. The alteration of the "MiC-Ready" design and the associated works;
d. The off-site payment terms under certain restrictions;
e. The quality assurance and quality check plan;
f. The shortened contract period.

All the above flexibility in the tender allows a more competitive bid to be returned and the tender assessment system can help to ensure a technically feasible, commercially competitive and financially well considered tender to be chosen. With all these measures, the tender bids returned are well within budget and comparable to the construction cost based on the traditional cast-in-situ method. The tender has been just awarded and it is known that more and more "MiC" projects will be launched in Hong Kong. It is believed that with the experience of these pioneer projects and with "MiC" method becoming more mature to the market, the construction cost will be much lower than the current pricing. We expect that this project will be completed in a faster way, with better quality, more economical with improved environmental sustainability and will reduce the health and safety risks in using the "MiC" method.

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