

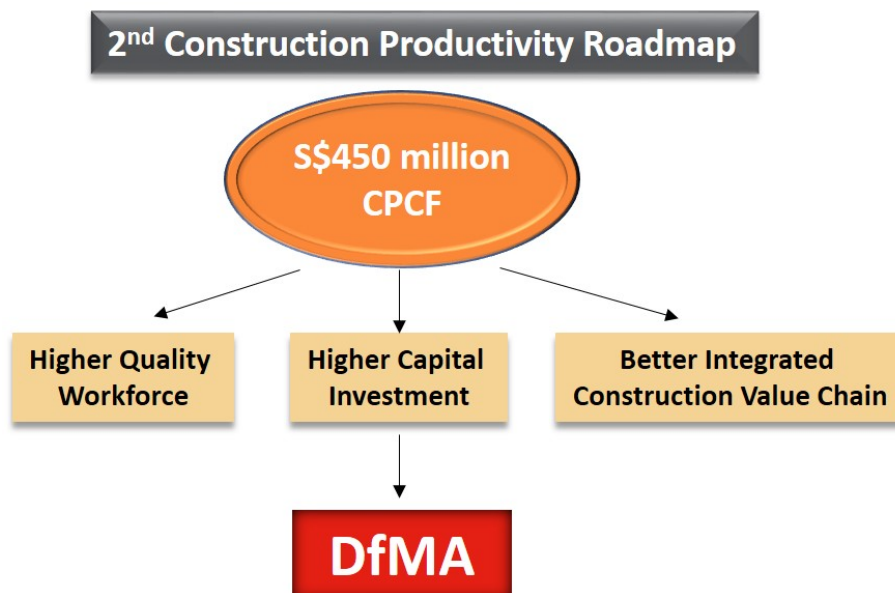
DESIGN FOR MANUFACTURING & ASSEMBLY - PREFABRICATED PRE-FINISHED VOLUMETRIC CONSTRUCTION (DfMA - PPVC)

Introduction

To further raise the Singapore's construction productivity level, the Government, on 10 March 2015, announced that a fresh funding of S\$450 million will be set aside for the 2nd tranche of Construction Productivity Capability Fund (CPCF). This additional funding aims to help push for higher productivity gains in the industry over the next 3 years (June 2015 to May 2018). To-date, approximately 9,000 firms from the built-environment sector have benefitted from this scheme. Under this 2nd Construction Productivity Roadmap, a target average site productivity improvement of 2% to 3% (per annum from 2010 to 2020) has been set.

A S\$150 million Public Sector Construction Productivity Fund (PSCPF) has also been introduced in February 2017 to spur the adoption of innovative and productive solutions for public sector projects.

In line with the above, the Government is steering the Singapore's construction industry towards the direction of having more projects to adopt Design for Manufacturing and Assembly (DfMA).



What is DfMA?

DfMA refers to the practice of manufacturing as many building parts as possible in a factory; prefabricated parts are then assembled on site. Whilst game-changing technologies such as Prefabricated Bathroom Units (PBUs), Prefabricated Pre-finished Volumetric Construction (PPVC), Cross Laminated Timber (CLT), Glued Laminated Timber (Glulam), etc. are examples of DfMA concept, this article focuses on PPVC, as the usage of PPVC has increased recently due to the continued Government's initiatives to improve productivity, such as stipulating mandatory requirement for the adoption of PPVC for new developments sold under selected Government Land Sales (GLS) Programme.

What is PPVC?

PPVC comprises free-standing volumetric modules made of multiple units complete with internal finishes, fixtures and fittings which are manufactured in factories, and are then transported to site for installation in a 'lego-like' manner. There are 3 types of PPVC system available in the market; concrete, steel and hybrid of concrete and steel PPVC modules.

Why PPVC?

PPVC supports the ethos of DfMA by having majority of the construction works to be carried out off-site in a controlled manufacturing environment.

According to data published by BCA, PPVC can potentially improve productivity by up to 50% in terms of manpower and time savings, depending on the complexity of the projects. By shifting more construction works off-site, it also helps to minimise dust and noise pollution as well as improve site safety.



Source: Screenshots taken from video taken during BCAA's seminar 'Prefabricating the Future - A Local PPVC Experience - NTU Nanyang Crescent Hostel'

BCA’s Guidelines on PPVC - Minimum Requirements

For building or component of the building on selected land parcels sold under the GLS Programme on or after 1st December 2015, BCA stipulates the minimum requirements for PPVC which the main contractor needs to comply to. The minimum PPVC requirements extracted from the *Code of Practice on Buildability 2017* are summarised as follows:

- Minimum Level of Use of PPVC

It shall be 65% of the total super-structural floor area of the building or the component of the building that is to be used for residential or private dwelling purposes. The total super-structural floor area refers to the total constructed floor area of the building consisting of the ground floor and all floors above the ground floor, but excluding any floor area constructed for use as a roof or car park.

- Minimum Level of Finishing and Fittings to be Completed Off-Site

Element	Minimum Level of Completion Off-Site
Floor finishes	80%
Wall finishes	100%
Painting	100% base coat, only final coat is allowed on-site
Window frame and Glazing	100%
Doors	100%, only door leaves allowed for on-site installation
Wardrobe	100%, only doors allowed for on-site installation
Cabinet	100%, only doors allowed for on-site installation
M&E including water & sanitary pipes, electrical conduits & ducting	100%, only equipment allowed for on-site installation
Electrical sockets and light switches	100%, only light fittings to allowed for on-site installation

Reference: Code of Practice on Buildability 2017

- Water Tightness and Prevention of Corrosion

If steel is adopted as the primary structural material for the PPVC system, it shall be galvanised in accordance to ASTM A 123/A 123M or equivalent standards. The PPVC modules shall also be designed and fabricated to prevent water from entering and to allow any water in between the module and façade and in between modules to be properly discharged and drained completely. Intended and potentially exposed wet floor areas shall be treated with waterproofing membrane to ensure water-tightness.

Cost and Time Implications

The estimated cost premium of adopting PPVC is approximately 10% to 15% of the total construction cost, mainly driven by the following factors:

- Higher Cost Outlay

The current practice for assessment and payment of works are limited to work done on-site, hence, contractors are required to pay for the initial cost of prefabricating the modules in the factory. To minimise their financial risk, contractors may then charge a higher price to the developer and may also front load the contract sum to recover the cost of prefabrication in the shortest time.

- Off-Site Yard

Off-site prefabrication often requires two off-site yards; carcass prefabrication factory and finishes & fittings installation yard. Additional costs are incurred for land rental and sending/stationing Resident Engineer (RE) or Resident Technical Officer (RTO) at overseas factory.

- Mechanisation and Lifting System

PPVC module weighs about 15 to 20 tonnes generally and require heavy-duty cranes (which would definitely cost more) to lift and stack the modules. During hoisting, module will undergo strong force, hence careful planning should be carried out to minimise hoisting time.

- Transportation to Site

LTA Permit

LTA permit is required for laden or unladen vehicles that exceeds 2.6m wide when travelling on controlled roads; or with a rear overhang of load of 1.8m or 40% of the vehicle length, whichever is lesser; or having more than its allowable weight limit.

Time of Delivery

Where the site is in vicinity of a school, delivery may be restricted during school peak hours (e.g. 0700 to 0900, 1700 to 1900, etc.). Marshalls may also be required to regulate traffic flow.

Auxiliary Police Escort

Auxiliary police escort is necessary if the laden or unladen vehicles exceeds 3.4m wide; or having more than 80 tonnes in weight; or with an overall height of more than 4.5m. Auxiliary police escort is only allowed from 1900 hours to 0500 hours on major roads and from 2300 hours to 0500 hours on expressways. Thus, if affected, it will inevitably increase cost as night works are being carried out.

Protection Works

During transportation, modules are vulnerable to damages and thus require protection works to safeguard the finishes and fittings. More materials may be necessary to repair the damages.

- Construction Schedule

To ensure optimization of design, there is a need for increased coordination between Architect, Engineer, Contractor and Manufacturer which may translate to a time-intensive design process. However, time-saving can be achieved during construction stage through overlapping of off-site prefabrication works and on-site construction works for piling and basement works.

Contractual Implications

With the adoption of PPVC, most of the traditional construction processes which are otherwise labour intensive will be carried out off-site in factories which embrace more prefabrication techniques. The prefabricated modules which come almost equipped with finishes and fittings will be transported to the site for final assembly or installation.

Given that the Government is backing the move to PPVC so heavily, it will be prudent to consider some of the salient contractual and practice matters arising from the adoption of PPVC.

Needless to say, the matters as suggested below would have to be dealt with by way of a set of supplementary provisions in the Contract for the arrangements to be effective.

- Payment Issues

Currently, the payment provisions in most standard forms do not provide for payment of materials stored or works carried out off-site. If the payment provisions are left unamended, the contractor will be exposed to significant expenditure outlay as payment cannot be sought under the contractual certification machinery until the modules are transported to site. Consequently, the immediate concern that faces most contractors for projects adopting PPVC is whether developers are willing to consider making payments under the Contract for PPVC works carried out off-site.

Whilst the Public Sector Standard Conditions of Contract ("PSSCOC") contains an Option Module which deals with payment for materials or goods stored off-site, this is subject to several requirements being met:

1. The storage location has to be in Singapore
2. The progress of Contract is such that the Superintending Officer is satisfied that the materials or goods cannot be fully and incorporated into the Works
3. There is inadequate storage space at the Site

Hence, the Superintending Officer's power to certify payment for materials stored off-site is not unfettered. His certification powers are confined by the limitations expressed under the provisions of the Option Module. For example, if the off-site facility for storage of the PPVC modules is not within the territorial limits of Singapore, arguably speaking, the Superintending Officer does not have the power to certify payment.

Unlike the PSSCOC, the Singapore Institute of Architects Articles and Conditions of Building Contract and the REDAS Design and Build Conditions of Contract do not contain similar payment provisions.

Cashflow is the lifeblood of the construction industry. This is best summed up with the old saying "revenue is vanity, cash flow is sanity and cash is reality". The consequences of a Contractor not having sufficient cash flow will lead to a financial strain in its business and ultimately, insolvency.

Whilst payments for off-site PPVC works may be considered, this cannot be unconditional. It is imperative to ensure that there are necessary safeguards in place to protect the Employer against a Contractor's insolvency. As such, a Contractor seeking off-site payments must be able to meet the following pre-conditions:

1. The PPVC modules are set apart or marked to identify the project, properly stored and protected against loss and damage
2. An advance payment bond for the value of off-site works to be included in interim certificates - an "on-demand" bond is a robust form of security where the surety agrees to pay the Employer upon receipt of a written demand, whether or not the Contractor is in default
3. Procurement of additional insurances where PPVC modules are stored outside of Singapore

Once the pre-conditions are established, parties may freely negotiate a payment framework which may be predicated on the progress of off-site PPVC works, defined stages of completion (which may take the following form) or otherwise:

1. Completion of fabrication of PPVC carcass (as verified by the RE or RTO)
2. PPVC modules complete with the minimum level of finishes and fittings to be installed off-site as specified in and in compliance with BCA's Code of Practice on Buildability
3. Final installation on site

What if an Employer does not assent to payment for off-site works or should parties fail to agree on the payment schedule? As the Contractor will have a more challenging time keeping his head above water, this will be factored in his tender price which eventually translates to a higher tender price and possible front-loading of the tender sum so as to alleviate his cashflow concerns and financial needs.

It bears asserting that the payment arrangements for PPVC works have to be considered and decided at an early stage so that the arrangements can be properly structured and provided for in the tender documents.

- **Advance Payment Bond**

Currently, the fabrication of PPVC carcass is mainly carried out in the Contractor's own or rented facility. In the event if the facility is located overseas (usually in Malaysia), the prefabricated carcass will then be transported from the overseas precast yard to another off-site factory in Singapore for installation of finishes and fittings.

In considering the value of the advance payment bond to be provided by the Contractor, the amount should not simply account for the value of the PPVC carcass but also consider the “minimum level of finishing and fittings to be completed off-site” stipulated under BCA’s Code of Practice on Buildability 2017. This would include the cost of delivery, supply and installation of the finishes and fittings, carpentry and mechanical, electrical and plumbing (MEP) works as well.

- Insurances

In terms of insurance arrangements, an off-site storage and inland transit endorsement in a Contractor’s All Risks Policy (“CAR Policy) would no longer suffice as these policies have territorial limits which cover limits that are usually “anywhere in Singapore in connection with the Works”.

Under such circumstances, the Contractor will have to arrange with the insurer to issue another policy in Malaysia (or the country where off-site fabrication takes place) to obtain insurance coverage of the full value of the PPVC modules or what is commonly known as the Property All Risks Policy.

Similarly, it will also be necessary for the Contractor to procure a proper Marine Cargo insurance policy to cover shipments or transit of the PPVC modules from Malaysia (or the country where off-site fabrication takes place) to Singapore.

In short, a Contractor has to procure and provide the Employer additionally with the Property All Risks Policy and Marine Cargo insurance policy which are to be issued in the joint names of both the Contractor and Employer as long as the PPVC modules are stored in an overseas location.

- Nominated Sub-Contracts (NSCs)

The contractual arrangements of some of the NSCs would warrant some attention as well as it is no longer practical to deliver the bulk of the architectural and MEP components to and carry out installation on site.

Door frames, wardrobes and cabinets (except doors), sanitary wares, fittings, windows, electrical conduits, switches, etc. would now have to be delivered to the Contractor’s off-site facility instead for installation.

In the same vein, back-to-back provisions relating to payment arrangements, advance payment bond and insurances have to be provided for in the tenders of the NSCs or supply contracts where logistical arrangements and work processes will be affected by the PPVC works.

- Site Supervision

As the fabrication of the PPVC carcass and the installation of the finishes and fittings of the modules are carried out in separate locations, the Employer will need to consider the appointment of additional REs or RTOs at these locations to supervise and monitor the progress of works and for purpose of quality control.

- Other Practical Considerations

Once the design is confirmed and the PPVC modules proceed into mass fabrication, variations should be limited to avoid any rippling effects on time and cost.

The total number of floors which is achievable within the maximum allowable building height control for the site may be reduced through the adoption of PPVC. This is due to the cumulative thickness created by the stacking of the PPVC modules which comes complete with a floor slab and ceiling. Likewise, the volumetric-massing approach could possibly also have some knock-on effects on the building efficiency/saleable floor area. Having said, these could be quite negligible and would depend on the PPVC system adopted by the Contractor.

Aesthetically, the Architect might have to work closely with the PPVC fabricators to develop solutions to fully optimise the design.

Conclusions

With the increasing number of GLS selected for mandatory adoption of PPVC, the message is very clear that it is important for the construction industry to have a mindset change in accepting and adopting productive technologies and remain flexible to changes in the business environment. The early involvement of Design Consultants and Contractor is henceforth important to achieve time and cost saving as well as design optimisation.

On the face of it, whilst the adoption of PPVC might create some challenges in the building efficiency and limit creativity of the building design, there is no doubt these will be improved in years to come with more advanced technologies and methods. In the meantime, it is important that the construction community understands the challenges and limitations of adopting PPVC technology.

The industry is still going through the learning curve of adopting PPVC, inevitably there are many other considerations that need to be thought through and resolved; such as:

- payment for off-site works including ensuing matters such as advance payment bond and procurement of additional insurances
- alignment of payment provisions of nominated sub-contracts or supply contracts with the main contract
- appointment of additional REs or RTOs at the off-site factories
- possible knock-on effects on building efficiency, saleable floor area, number of storeys, etc. that can be constructed

As an aside, it remains to be seen whether the Government will be receptive to recommendations to amend the payment schedule of the Sales and Purchase Agreement as stipulated under Schedule 1 of the Housing Developers (Control and Licensing Act) Cap. 130 so that this aligns with the payments of the off-site works. Undoubtedly, this will be much

welcomed by the industry and further encourage developers to consider alternative payment arrangements for off-site works.

As part of our commitment of excellent service to our Clients and to leverage our early involvement in projects with PPVC, Arcadis Singapore has translated our experience into streamlining our in-house practices to address the above considerations and making the necessary amendments to our front-end documents accordingly.

Arcadis Singapore would be pleased to share and give a presentation should you be interested to find out more information on PPVC.

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