

Modular Integrated Construction

Introduction

Modular Integrated Construction (MiC) refers to a construction method whereby free-standing volumetric modules (with finishes, fixtures, fittings, etc.) are manufactured off-site and then transported for constructing buildings. Proven benefits include improved site safety, more efficient and better quality control, shortened construction period, less construction waste, less demand for on-site labour, less disturbance and nuisance to the neighbourhood, etc., not just contributing to the quality and sustainable built-environment but also help ease some of the challenges of the local construction industry. To encourage MiC, the Buildings Department (BD) has formulated streamlined measures and guidelines to facilitate the industry in meeting the relevant standards and requirements under the Buildings Ordinance (BO).

Considerations Unique to MiC

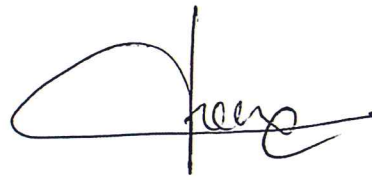
2. Similar to the use of prefabricated building components, the project team should engage the MiC suppliers at the early design stage to sort out the issues usually not encountered in conventional in-situ construction. Apart from the extent of standardisation and buildability of such modules, the mode of delivery with due regard to the specific site conditions, the issues that may arise from meeting the relevant requirements including those on supervision as well as the programme of plan submissions to the BD should be considered in advance. General guidelines on the design and quality control requirements under the BO for MiC are given in Appendices A and B respectively.

Pre-submission Enquiry

3. Authorized Persons and Registered Structural Engineers are encouraged to make use of the established mechanism of pre-submission enquiry service mentioned in PNAP ADM-19 to clear with the BD in the early design stage unconventional design or performance of a modular prototype for acceptance under the BO before preparing the detailed designs. A determination would be available within 45 days.

Pre-acceptance of MiC Systems or Prototypes

4. Furthermore, the BD has set up a pre-acceptance arrangement for granting in-principle acceptance to individual MiC systems/components or prototypes on specific performance as listed in Appendix C. Also, a determination would be available within 45 days. Details of the arrangement are available in BD's website www.bd.gov.hk. Nevertheless, the pre-acceptance is not a pre-requisite for the approval of building plans.

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(CHEUNG Tin-cheung)
Building Authority

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Design Requirements for Modular Integrated Construction

Fire Safety

The fire protection or performance of elements of construction of MiC should be addressed. Non-code-compliant designs should be justified for having equivalent performance as the prescriptive standards and, where necessary, supported by fire engineering assessments as stated in the Code of Practice for Fire Safety in Buildings 2011.

Joints and Gaps

2. Modular constructions would usually entail more joints and gaps including those in drainage pipes and building envelope which are prone to water leakage.

Structural Design

3. The requirements on the design and construction of reinforced concrete, precast concrete and structural steel given in the Code of Practice for Structural Use of Concrete, Code of Practice for Precast Concrete Construction and Code of Practice for Structural Use of Steel also apply to MiC elements. Particular considerations should be given to the following design aspects:

(a) **Stability**

A building structure comprising modular units must possess adequate stability to resist wind and other lateral loads. Consideration should also be given to temporary stability during assembly and installation of the modular units. Adequate support should be provided at all stages of installation to ensure that stability is maintained;

(b) **Robustness and integrity**

The overall structural system comprising modular units should be designed to be robust and be able to resist disproportionate collapse. Structural integrity should be provided by tying all modular units and in-situ elements together horizontally and vertically. The modular units should be designed to be capable of sustaining accidental loading in such a way as to prevent the extent of any resulting collapse of individual modular unit being disproportionate to the cause of the collapse;

/(c) ...

(c) Design for temporary stages

Structural action and load path may be different during the temporary stages of construction, including fabrication, lifting, transportation, assembly and installation, and may result in higher stresses in individual MiC elements. Consideration should be given to the temporary imposed loading on the modular units during each stage of construction. The temporary stability and integrity of the modular units at all stages of construction should be ensured; and

(d) Design for movements

The MiC system should be designed to accommodate cumulative movements, usually by the provision of joints, occurred throughout the various construction stages and during its service life. Consideration should be given to the various causes of movements such as creep deformation, shrinkage, differential movement, thermal movement, etc. with due regard to the fact that such movements may be short-term or long-term and may or may not be coexistent or occur concurrently. Allowance should also be made for fabrication and installation tolerances.

Provisions for Maintenance

4. The provision of access points, inspection pits or accessible recesses to facilitate inspection and repair/replacement of structural connections, drainage pipes, building services and joints should be considered during the early design stage of the MiC system.

Quality Control and Supervision of MiC

Quality Assurance Scheme

Modular units are to be fabricated by a factory with ISO 9000 or equivalent quality assurance certification. This will be imposed as a condition under item 6 in section 17(1) of the BO when giving approval of plans.

2. Upon approval of plans, a requirement will also be imposed under regulation 10 of the Building (Administration) Regulations (B(A)R), to require submission of a copy of the Quality Assurance Scheme of the MiC supplier prior to the application for consent to the commencement of the superstructure works. Such submission should be appended with a statement signed by the Authorized Person (AP) and Registered Structural Engineer (RSE) to confirm that the scheme has adequate provisions in ensuring the quality of production complying with the provisions of the BO and the approved plans.
3. The Quality Assurance Scheme should cover the following items:
 - (a) Quality control tests of materials;
 - (b) Calibration of laboratory equipment for quality control tests;
 - (c) Efficiency and proper operation of equipment at the prefabrication factory;
 - (d) Production process;
 - (e) Testing procedures and requirements;
 - (f) Frequency and extent of inspection by in-house staff and independent parties¹; and
 - (g) Frequency and extent of audit by in-house staff and independent parties.

Quality and Qualified Supervision

4. Approval of plans will be imposed with a condition under item 6 in section 17(1) of the BO to specify that qualified supervision is to be provided by the AP, RSE and the Registered Contractor (RC) for the fabrication, assembly, installation and examination of modular units and pre-installed finishes.

¹ "Independent parties" refer to parties not under the direct employment of the prefabrication factory (i.e. either a certification body under the Hong Kong Certification Body Accreditation Scheme of the Hong Kong Accreditation Service (HKAS) or an inspection body under HKAS's Hong Kong Inspection Body Accreditation Scheme).

5. The AP and RSE should assign their respective Quality Control Supervisory Team (QCST) to supervise the modular unit production work in respect of fire resisting constructions (such as fire resisting doors and fire resisting pipe collars), drainage works, structures, etc. in accordance with the requirements stipulated in the PNAP APP-158. Similarly, the RC should assign a Quality Control Co-ordination Team (QCCT) to supervise the modular unit production work in the prefabrication factory. The AP, RSE and the Authorized Signatory (AS) of the RC should respectively determine the required qualification of the supervisory personnel and necessary frequency of supervision of QCST and QCCT subject to the minimum standards in Table 1 below.

Table 1 Minimum Qualification and Supervision Frequency of QCST and QCCT

	AP Stream	RSE Stream	RC Stream	
Qualifications of Supervisory Personnel	T3*	T3*	T3*	T1*
Supervision Frequency	Weekly	Weekly	Weekly	Continuous

* T3/T1 refers to Grade T3/T1 Technically Competent Person equivalent as stipulated in the Code of Practice for Site Supervision

6. The names and qualifications of the supervisory personnel assigned by the AP, RSE and RC respectively should be recorded in an inspection log book. The details of production, inspection, auditing and testing of modular unit should be recorded in the log book by the supervisory personnel. The log book should be kept in the prefabrication factory and a copy of it should be kept at the building site office and, when required, produced to officers of the BD for inspection.

7. In addition, the AP, RSE and the AS of the RC should inspect and carry out audit checks at the prefabrication factory at least once every month. A requirement will be imposed under regulation 10 of the B(A)R, when giving approval of plans to specify that a copy of the AP, RSE and AS's audit reports of the prefabrication factory duly endorsed by the AP, RSE and AS respectively are to be submitted to the BD for record purpose. These audit reports should also cover the quality and qualified supervisions by the respective QCST and QCCT.

8. As an alternative to the requirement for the audit checks by AP/RSE at the prefabrication factory specified in paragraph 7 above, the AP/RSE may consider carrying out on-site audit checks to the quality of the MiC elements delivered to the building site. In such situation, the AP/RSE is required to notify the Building Authority in writing before commencement of works, and to submit a copy of on-site audit reports on the quality of the MiC elements delivered to the building site to the BD for record purpose, covering the quality and qualified supervisions by the QCST. Minimum requirements of the on-site audit checks by the AP/RSE are given in the Annex.

Annex of Appendix B
(PNAP ADV-36)

**Minimum Requirements of the AP's/ RSE's On-site Audit Check
on MiC Elements Delivered to the Building Site**

The audit checks on the MiC elements delivered to the building site carried out by the AP/RSE as an alternative to the audit check on MiC elements at the prefabrication factory should comply with the requirements specified in paragraph 2 below.

2. The rate of sampling for the audit checks shall be at least 1% of each type of modular units delivered to the building site. The audit check for each sample of the modular units should include the following items, where applicable:

Works Item		Scope
AP		
1	The setting out and interior	<ul style="list-style-type: none"> ● Check critical dimensions including storey height, projections, balconies, utility platforms, A/C platforms, protective barriers, internal areas, exit routes, etc. ● Check conformity with general layout
2	Installation of windows and flue apertures	<ul style="list-style-type: none"> ● Check minimum areas of glazing and openable areas of prescribed windows and windows for rooms containing soil or waste fitment and water tightness in accordance with PNAP APP-116 ● Check position and dimensions of flue apertures ● Check provisions required under modification/exemption
3	Provision of Barrier Free Access	<ul style="list-style-type: none"> ● Check provisions and critical dimensions of bathroom, toilets, ramps, corridors, lobbies, doors, handrails, signage, tactile guide path, etc.
4	Drainage	<ul style="list-style-type: none"> ● Check provision of sanitary fitments ● Check drainage works including material, dimensions, water seal traps, vent or anti-siphonic pipes and any other necessary components
5	Fire resisting construction ¹	<ul style="list-style-type: none"> ● Check materials, fire protection of structural elements and construction of fire barriers and installation of proprietary products such as FRR of fire doors, smoke seal, self-closing device, pipe collars, etc.
6	Finishes and fittings	<ul style="list-style-type: none"> ● Check water proofing where appropriate such roof, shower areas, etc. including reports of water ponding test/spray test for impermeable construction ● Check provision of required mechanical ventilation and artificial lighting ● Check provision of required fire services installations such as smoke detectors and sprinkler heads for open kitchens, etc.
7	Others	<ul style="list-style-type: none"> ● Any other items considered essential by the AP for the project

¹ Open-up audit check of fire resisting dry walls is required.

RSE		
1	Steel reinforcing bars	<ul style="list-style-type: none"> ● Opening-up of the concrete surface at 3 locations, each with an area of 100mm x 300mm, to check the size, pattern and layout of the steel reinforcing bars; and the concrete covers ● Measurement of the concrete cover to steel reinforcing bars by covermeter at 6 locations, each with 6 readings taken in an area of 450mm x 450mm ● Material testing reports
2	Concrete	<ul style="list-style-type: none"> ● Concrete strength testing ^{2 #} of concrete cores taken at 3 locations ● Material testing reports
3	Structural steel	<ul style="list-style-type: none"> ● Non-destructive testing of welded joints by means of visual inspection, magnetic particle inspection/ dye penetration inspection and ultrasonic examination, where appropriate^{3 #} ● Tensile strength testing^{4 #} of one specimen for every 40 tonnes of each section or plates of same thickness from the same cast to be used for fabrication of modular units selected at random by the QCST in the prefabrication factory ● Material testing reports
4	Finished products	<ul style="list-style-type: none"> ● Concrete surface ● Steel surface/ corrosion protection ● Sizes, dimensions and fabrication tolerances ● Starter steel reinforcing bars ● Shear connectors
5	Inspection records	<ul style="list-style-type: none"> ● Log books of the supervisory personnel assigned by the RSE in the QCST
6	Others	<ul style="list-style-type: none"> ● Any other items considered essential by the RSE for the project

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² Refer to the requirements specified in CS1:2010.

³ Refer to the requirements specified in section 14.3.6 of the Code of Practice for the Structural Use of Steel 2011.

⁴ Refer to the requirements specified in BS EN 10002-1:2001 or BS EN ISO 6892-1:2009.

[#] The test should be carried out by a laboratory accredited under the Hong Kong Laboratory Accreditation Scheme (HOKLAS) or by other laboratory accreditation bodies which have reached mutual recognition agreements/arrangements with HOKLAS for the particular test concerned. Test results should be reported on a HOKLAS Endorsed Certificate and submitted within 60 days of the delivery of the modular units to the building site.

Pre-acceptance Application Checklist for MiC

This application checklist aims to remind AP and RSE of the essential information which should be contained in the plans and supporting documents accompanied with the application. The checklist should be completed by ticking the items relevant to the application and any other information essential for the MiC system should be listed out in Section 10.

The BD will conduct regular review on this application checklist in the light of experience gained in processing different MiC systems, feedbacks from the building industry on the use of various MiC systems and technological development in the relevant fields.

- Essential information to be provided on plans
 △ Essential information to be provided in the supporting document accompanied with the plans

Section		Essential Information
1.	General	<ul style="list-style-type: none"> ○ General notes on compliance with applicable regulations / codes of practice / design manual / guidelines ○ General building plans (plans of all floors, sections and all elevations) in scale not less than 1:100 with full dimensions ○ Structural plans in scale not less than 1:100 showing the layout and dimensions of all structural elements, modular units, structural connections and locations of movement joints ○ Intended height and use of building ○ Intended use of every module of the system ○ Table indicating the required and provided sanitary provisions ○ Standard details, if applicable, gas flue aperture, balcony, A/C platform, curtain/window wall, non-structural external wall system/cladding, sunken slab, impermeable construction of rooms with water supply, protective barrier, projections, vertical greening, pipe ducts etc. ○ Standard details to show the method of sealing up gaps of partition or internal wall, between modules interface △ Job reference (both local and international), if any
2.	Fire Safety	<ul style="list-style-type: none"> ○ Detail drawings to illustrate compliance of the Code of Practice for Fire Safety in Buildings (FS Code) in term of means of escape, fire resisting construction and means of access for firefighting and rescue, for example: <ul style="list-style-type: none"> (a) Occupant capacity, required and provided no. and width of exit doors and exit routes; (b) Direct distance and travel distance of exit routes;

Section	Essential Information
	<ul style="list-style-type: none"> (c) Table of construction and materials for walls, floors, columns, beams and stairs with fire resistance rating (FRR) of elements of construction; (d) FRR of fire barriers separating different occupancies, uses, compartment and the areas of special hazard if applicable; (e) Fire resisting construction for the protected exit route if applicable; (f) Fire protection for vertical shafts and required staircase; (g) Non-combustibility requirements for cladding/external wall/curtain wall including the insulation/water proofing materials; (h) Limited combustibility requirements for linings/coverings of internal wall, ceiling, floor and decorative finishes; (i) Non-combustibility requirements for acoustic and thermal insulation in ductings and concealed location; and (j) Provision of fireman's lift and firefighting & rescue stair (FRS) (indicated with measurements of actual passage from fireman's lift and FRS at critical locations), if applicable. <p>△ Documental proofs to illustrate compliance of FS code, for example:</p> <ul style="list-style-type: none"> (a) Fire test reports for the fire rated materials, intumescent paints, doors and wall systems used; (b) Test reports for materials of limited combustibility and non-combustibility; and (c) Fire safety review of the system conducted by fire safety engineer, if applicable.
3. Lighting and Ventilation	<ul style="list-style-type: none"> ○ Calculation of area of all rooms requiring provision of prescribed windows ○ Area calculations for proposed prescribed windows including areas of glazing and openable sash ○ Provision of natural light and ventilation for rooms containing soil or waste fitments
4. Drainage	<ul style="list-style-type: none"> ○ Detail drawings to illustrate compliance of Building (Standards of Sanitary Fitments, Plumbing, Drainage Works and Latrines) Regulations, for example: <ul style="list-style-type: none"> (a) Proper design of discharge for soil and waste fitments including traps, internal dimension, bends, cleaning access and materials of soil and waste pipes, and their connection details to vertical stacks;

Section	Essential Information
	<ul style="list-style-type: none"> (b) Provision of anti-siphonage pipes and ventilation pipes; (c) Provision of flushing cisterns, flushing pipes of adequate internal dimension and overflow pipes for soil fitments; (d) Connexions of pipes and fittings shall be designed in a manner to ensure water tightness and to prevent escape of foul air; (e) Proper design of rain water discharge for roofs, balconies, canopies and utility platforms etc. if applicable; (f) Level difference between internal floor and adjoining external ground/flat roof not less than 150mm; and (g) Arrangements for discharge from air conditioner condensate disposal system, planters and landscaped areas to the surface water drainage system. ○ Provision of surface water discharge for cantilevered structures exposed to weather ○ No pipework for a domestic unit shall protrude into the unit under separate occupancy ○ Common above-ground soil / waste / rainwater stacks and underground drains located in common parts of the building (PNAP APP-93) ○ No water-borne pipe embedded in structural elements (PNAP APP-105)
5.	<p>Barrier Free Access</p> <ul style="list-style-type: none"> ○ Provision of access and facilities for persons with a disability (Chapter 2 of Design Manual Barrier Free Access 2008 is relevant)
6.	<p>Structure</p> <ul style="list-style-type: none"> ○ Structural system and design loads △ Vertical and lateral load transfer mechanism △ Structural stability △ Robustness ○ Corrosion protection ○ Fire protection of structural elements ○ Structural connections between modular units and between modular units and cast in-situ structural elements △ Design for temporary stages (lifting, storage, installation, etc.) including the design of lifting frames, if any ○ Design Codes*: Code of Practice for Structural Use of Concrete, Code of Practice for Precast Concrete Construction and Code of Practice for Structural Use of Steel, and / or * others, please specify _____ ○ Material specifications and compliance standards ○ Durability and workmanship requirements

Section	Essential Information
7. Quality Assurance	<ul style="list-style-type: none"> △ Certification on ISO 9000 quality assurance to prefabrication factory △ Quality Assurance Scheme of the prefabrication factory appended with a statement signed by the AP and RSE to confirm that the scheme has adequate provisions in ensuring the quality of production complying with the provisions of the Buildings Ordinance. The scheme should cover those items as listed in paragraph 3 of Appendix B of PNAP ADV-36
8. Fabrication, Storage, Transportation & Installation	<ul style="list-style-type: none"> △ Description of the construction stage with pictorial illustration including the fabrication, logistic, assembly and installation aspects of MiC system as follows (may be supplemented by Building Information Modelling files in digital format as specified in PNAP ADV-34): <ul style="list-style-type: none"> (a) Manufacturing process in prefabrication factory (b) Method of lifting in the prefabrication factory (c) Means of transportation with limitation stated (d) Method of preventing damage to the modular units during storage, transportation and installation (e) A complete step-by-step pictorial safe work procedures and sequence illustration of the entire process of the on-site lifting, movement and installation of the MiC ○ Fabrication and installation tolerances
9. Maintenance	<ul style="list-style-type: none"> ○ Provision of pipe duct/pipe well (PNAP APP-93) ○ Access points for inspection of drains to be housed by sunken slabs ○ Accessible recess at strategic locations for the repair / replacement /monitoring of the critical structural members and modular units connections, e.g. joint fillers, waterproofing arrangement, structural connections, e.g. bolts / welds / interlocking, etc., if any △ “Design for Safety” considerations on access for future maintenance and minor repair of external features, A/C units or cladding, etc., if any (PNAP ADV-14) △ User manual with safety notices and instructions for alteration, drilling and installation of addition fittings etc.

Section		Essential Information
10.	Other Essential Information	<p>△ Justifications and substantiations for application for exemption/modification accompanied with supporting documents</p> <p>Other information essential for the concerned MiC system</p> <p>(Please specify):</p>

* Delete as appropriate

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