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建造業議會

Reference Material

Heavy Lifting Operation for MiC Projects

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FOREWORD

This is the fifth of a series of Reference Materials on Modular Integrated Construction (MiC) projects issued by the Construction Industry Council (CIC) under the theme of MiC. This reference material gives information on the safe use of tower cranes and mobile cranes for on-site lifting for MiC projects in Hong Kong, such as the key parties/personnel involved in the lifting operation, the preparation and planning work needed for the operation, prior to the works, etc. The engineering aspects of crane selection and location, crane base design, crane erection, height alteration and dismantling, technologies facilitating crane safety operation, etc., related to the safe use of cranes are given. This reference material does not cover other commonly used heavy lifting equipment in the off-site prefabrication factory, such as gantry crane, etc.

This Reference Material gives guidance on the safe and good lifting operation and, as such, its recommendations are not mandatory.

This Reference Material was prepared by Dr Thomas Lam. Mr Thomas Tong and Dr Richard Pang have provided very valuable suggestions and comments on this Reference Material in the preparation. Messrs William Tang (Liebherr-Singapore Pte. Ltd.), Patrick Tang (Hong Kong Construction Association), Felix Tang (Hong Kong Science and Technology Park), Alan Kan (Setwin) and Philip Lai (WSP), and many organizations with MiC knowledge and experience, in particular Development Bureau, Buildings Department, Housing Department and Labour Department, have also provided very useful comments and information in the preparation of this Reference Material. These contributions are gratefully acknowledged.

Practitioners are encouraged to comment at any time to the CIC on the contents of this Reference Material, so that improvements can be made to future editions.

Industry Development
Construction Industry Council

DISCLAIMER

ENQUIRIES

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PREFACE

The Construction Industry Council (CIC) is committed to seeking continuous improvement in all aspects of the construction industry in Hong Kong. To achieve this aim, the CIC forms Committees, Task Forces and other forums to review specific areas of work with the intention of producing Alerts, Reference Materials, Guidelines and Codes of Conduct to assist participants in the industry to strive for excellence.

The CIC appreciates that some improvements and practices can be implemented immediately whilst others may take more time for implementation. It is for this reason that four separate categories of publication have been adopted, the purposes of which are given as follows:

Alerts	The Alerts are reminders in the form of brief leaflets produced quickly to draw the immediate attention of relevant stakeholders to the need to follow some good practices or to implement some preventive measures in relation to the construction industry.
Reference Materials	The Reference Materials provide standards or methodologies generally adopted and regarded by the industry as good practices. The CIC recommends the adoption of the standards or methodologies given in the Reference Materials by industry stakeholders where appropriate.
Guidelines	The Guidelines provide information and guidance on particular topics relevant to the construction industry. The CIC expects all industry stakeholders to adopt the recommendations set out in the Guidelines where applicable.
Codes of Conduct	The Codes of Conduct set out the principles that all relevant industry participants should follow. Under the Construction Industry Council (Cap 587), the CIC is tasked to formulate codes of conduct and enforce such codes. The CIC may take necessary actions to ensure compliance with the codes.

To allow us to further enhance this publication, we encourage you to share your feedback with us, after you have read this publication. Please take a moment to fill out the Feedback Form attached to this publication and send it back to us. With our joint efforts, we believe our construction industry will develop further and will continue to prosper in the years to come.

ABBREVIATIONS

ACS	Anti-collision system
AI	Artificial Intelligence
AS	Authorized Signatory of Registered General Building Contractor or Registered Specialist Contractor
ASA	Accredited Safety Auditor
ASLI	Automatic Safe Load Indicator
BD	Buildings Department
BO	Buildings Ordinance (Cap. 123)
CME	Competent Mechanical Engineer
CoP	Code of Practice
CSSR	Construction Sites (Safety) Regulations (Cap. 59I)
CWRO	Construction Workers Registration Ordinance (Cap. 583)
FIUO	Factories and Industrial Undertakings Ordinance (Cap. 59)
FIUR	Factories and Industrial Undertakings Regulations (Cap. 59A)
HD	Housing Department
HKIC	Hong Kong Institute of Construction
LALGR	Factories and Industrial Undertakings (Lifting Appliances and Lifting Gear) Regulations (Cap. 59J)
OSHC	Occupational Safety and Health Council
RC	Registered Contractor registered under the Buildings Ordinance
RFID	Radio Frequency Identification
RPE	Registered Professional Engineer
RSE	Registered Structural Engineer registered under the Buildings Ordinance
RSO	Registered Safety Officer
RSTC	Register of Specialist Trade Contractors
SSP	Safety Supervision Personnel
SWL	Safe Working Load
TCP	Technically Competent Person under the Technical Memorandum for Supervision Plans 2009 and the Code of Practice for Site Supervision 2009 (2021 Edition)
UWB	Ultra Wide Band

1. INTRODUCTION

A MiC building is constructed of modules, which are manufactured in an off-site prefabrication factory, and transported to the building site for installation and assembly. Installation and assembly require lifting of modules by cranes from a pick-up point to the designated locations for installation. For a typical 3.5 m high x 5.5 m long x 3 m wide module, the lifting weight could go up to 30 tonnes, and 15 tonnes for a reinforced concrete module, and a steel module respectively. Lifting of modules is very much similar to lifting of other construction elements except that it requires more careful planning at the onset and a higher precision of positioning since at times the view of the crane operator could be obstructed by other building elements constructed.

Two types of cranes are generally used for on-site lifting in a MiC project in Hong Kong: tower cranes and mobile cranes. This reference material does not cover other commonly used heavy lifting equipment in the off-site prefabrication factory, such as gantry crane, etc. The decision on the use of the type of cranes depends on project specifications, such as height of building structure, overall building footprint, site logistics, availability of loading and unloading areas, module pick-up point, etc. For projects in which either tower cranes or mobile cranes could be used, the decision would depend on site accessibility, setup requirement, footprint of crane, estimated downtime due to breakdown, etc.

Construction safety is the top priority and it is everyone's responsibility to ensure that the "Life first" spirit is embedded into the whole project life cycle, including the pre-construction planning, design, construction activities and lifetime maintenance and operation stage. On the safe use of cranes, there are requirements for establishing a safe system of work and undertaking a task-specific risk assessment, and hence providing suitable method statements for the operation, prior to commencement of the works. There are qualification and experience requirements for the personnel, and test, thorough examination and inspection requirements for the lifting appliances and lifting gear for the tower crane and mobile crane operation.

As a result of a tower crane collapse at a demolition site in Causeway Bay[1] in July 2007 during height-alteration operation, further enhanced safety measures specifically for the tower crane operation had been introduced. Special requirements are now in place for inspection and certification of tower cranes before installation, enhanced site supervision by professionals with relevant qualification and experience, proper keeping of maintenance and operation records and competence of the specialist contractors and working crew for the operation[2]. Another crane accident occurred on 7 September 2022. A tower crane collapsed onto containers at a construction site on Anderson Road, killing three workers and injuring six others.

In MiC projects where tower cranes are used, it is necessary to check at the onset of the project the availability of cranes for the project, in terms of crane capacity, radius of reach of the crane, etc. This could have a bearing on the viability of the project, module design, module specifications, building layout, etc., if there is no crane available to meet the capacity needs, nor available in time

[1] LegCo (2008). Paper for Legislative Council Panel on Manpower Safety in the Use of Tower Cranes on Construction Sites (LC Paper No. CB(2)2480/07-08(01)).
[2] Guidelines on Safety of Tower Cranes (CIC, 2010) and Code of Practice for Safe Use of Tower Cranes (LD, 2011).

for the project. After suitable tower cranes have been identified, the additional factor of siting the tower crane in the site merits early attention, in addition to the logistics and noise issues, because this will affect the effectiveness and productivity of the project.

This reference material lists out the key parties/personnel involved in the control and management of the lifting operation, their qualification and experience requirements, and the preparation and planning work needed for the operation, prior to the works. The engineering aspects of crane selection and location, crane base design, crane erection, height alteration and dismantling, technologies facilitating crane safety operation, etc., related to the safe use of cranes are given. More focus is placed on the tower cranes on those aspects, because tower cranes are more commonly used in MiC building projects.

2. CONTROL AND MANAGEMENT OF LIFTING OPERATION

2.1 General

2.1.1 Governing Legislations

The legal requirements governing the safe use of tower cranes and mobile cranes are mainly given in the Factories and Industrial Undertakings (Lifting Appliances and Lifting Gear) Regulations (Cap. 59J) (LALGR). Attention is drawn to the requirements and procedures for testing and examination of cranes under the LALGR and the British Standard BS 7121[3].

According to the LALGR, lifting appliance means a crab, winch, teagle, pulley block or gin wheel used for raising or lowering, and a crane, sheerlegs, excavator, pile driver, pile extractor, dragline, aerial ropeway, aerial cableway transporter or overhead runway, and also any part of any such appliance, and lifting gear means a chain sling, rope sling, ring or similar gear, and a link, hook, plate clamp, shackle, swivel or eyebolt.

2.1.2 Scope of Lifting Operation

The lifting operation of cranes should be taken to include the following:

(a) erection, dismantling and height alteration/transportation (herein called *erection work*);
(b) lifting; and
(c) inspection, examination and testing, and maintenance and repair.

The cranes, in this context, include tower cranes and mobile cranes. A list of the tower crane and mobile crane manufacturers is given in Appendix A.

The inspection, examination and testing, and maintenance and repair of tower cranes and mobile cranes, and lifting gear are particularly important to ensure their safety and reliability. Statutorily, there are three types of duties, as follows:

(a) inspection by a competent person;
(b) thorough examination by a competent examiner; and
(c) test and thorough examination by a competent examiner.

The frequency of test, thorough examination and inspection of tower cranes and mobile cranes, and lifting gear under the LALGR are given in Appendices B and C respectively. The regular maintenance of the critical parts of the cranes as per manufacturer's instructions is equally important, and should be carried out. A Maintenance Manual for the cranes and lifting gear should be prepared.

2.2 Parties Involved

Only competent personnel are permitted to carry out the lifting operation. The qualification, experience and training requirements for the personnel involved in the lifting operation are given in Appendix D.

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[3] BS 7121 - Code of practice for the safe use of cranes.

The personnel involved in the lifting operation of a MiC project are very much similar to those of a conventional building project. The personnel working in the lifting operation using tower cranes and mobile cranes are the same, though more personnel are involved in the tower crane operation.

There are *three* main parties involved in the lifting operation: *Project Engineer, Principal Contractor and Specialist Contractor*, as shown in Figure 1. The personnel working under each party and the additional personnel that have the responsibility for tower cranes are highlighted in yellow in the figure. The roles and responsibilities of these personnel can be found in the Code of Practice (CoP) for Safe Use of Tower Cranes (LD, 2011) and the CoP for Safe Use of Mobile Cranes (LD, 2017b). Their roles and responsibilities should also be read in conjunction with the Reference Material on Safety Roles and Responsibilities of Key Stakeholders in the Hong Kong Construction Industry (CIC, 2022).

For private development projects, the *erection work* of tower cranes is considered as a type of Case 2 or 3 temporary works as defined in Paragraph 4.9 of the CoP for Site Supervision 2009 (BD, 2021). The sequence of construction or method statements for this type of work are not required to be shown on the prescribed plans. This type of work may have an effect on the permanent structure by way of overstressing or overloading, and the engagement of a TCP of grade T5 (see Section 2.2.3(c)) is needed to certify the plans, design information and/or method statement of the temporary works which are to be submitted to the RSE/RGE. The person so appointed should also certify the completion of such works.

The control and management of the crane erecting work for public works projects are very much similar to those of the private development projects, in which case, an Independent Checking Engineer (ICE)[4], acting in the capacity of the TCP of grade T5, is engaged to examine the design and method statements of the design and erection of the tower crane, taking into consideration of the ground conditions, adequacy of foundation, support for the crane, etc.

A detailed account of the control and management of temporary works can be found in the Guide to Good Practice on Control and Management of Temporary Works prepared by the Hong Kong Temporary Works Forum (HK-TWf, 2021).

2.2.1 Project Engineer

The Project Engineer means the person engaged by the project client to develop, plan, design and supervise the works, who can be:

(a) the Registered Structural Engineer (RSE) appointed under Section 4 of the Buildings Ordinance (Cap. 123) (hereafter referred to as BO) for private project(s);

(b) a competent person whose appointment is, subject to prior agreement of the Building Authority, to take up the responsibilities and duties of a RSE for project(s) with

[4] The ICE shall be a professionally qualified engineer and a member of the Hong Kong Institution of Engineers or the Institution of Civil Engineers, UK or equivalent, whom the Principal Contractor considers has suitable experience and be acceptable to the Project Engineer.

exemption granted by the Building Authority from the procedures and requirements relating to the appointment of a RSE under Section 4 of the BO (e.g. for MTR projects);

(c) the engineer(s)/supervising officer of similar capacity for Housing Authority project(s);

(d) the engineer(s)/supervising officer as specified in the works contracts for public works projects;

(e) the independent checking engineer(s) of similar capacity appointed by the Principal Contractor at the request of the government departments for public works project(s).

There is a site supervision team to assist the Project Engineer to audit the *erection work* of the tower cranes.

2.2.2 Principal Contractor

The Principal Contractor is the Registered Contractor (RC) registered under Section 8A of the BO who enters into a contract with the project client to perform the construction works. The Principal Contractor has the overall responsibility for the control and management of the lifting operation. The Project Manager and Project Co-ordinator manage and co-ordinate the works on site. The Registered Safety Officer (RSO) carries out a task-specific risk assessment of the lifting operation prior to the work. In assessing the risks, he will liaise with the Project Engineer, representative of the Specialist Contractor, Competent Person and site supervision team; he/she will consult a Registered Professional Engineer (RPE) on issues related to structural and mechanical stability.

An Independent Safety Checker may be engaged to cerify the safety plan, method statement, the qualifications of the personnel, etc., and conduct safety workshops and safety audits, in respect of the lifting operation.

2.2.3 Specialist Contractor

The Specialist Contractor is a subcontractor of the Principal Contractor who enters into a contract with the Principal Contractor to perform the lifting operation. This Specialist Contractor means a firm registered under the Designated Trade of S10 Tower Crane (Erection, Dismantling and Altering Height) of the Register of Specialist Trade Contractors (RSTC)[5] administered by the CIC. The Designated Trade of S10 Tower Crane includes transporting, erecting, dismantling, altering height of tower crane (except renting and operating), and the site lifting operations.

A Responsible Person is appointed to exercise overall control of the lifting operation. This appointed person should have adequate training and experience to enable these duties to be carried out competently (LD, 2011). The Responsible Person is normally engaged by the Specialist Contractor. However, he/she can also be engaged by the Principal Contractor, so long as the person engaged has the adequate training and experience to enable him/her to discharge the duties competently.

[5] https://rstc.cic.hk/en/register-list.aspx

For tower crane operation, the following aadditional personnel are engaged:

(a) a Supervising Engineer[6] to directly supervise on site the erection, dismantling and height alteration operations of tower crane (see Section 10.2.1 of the CoP for Safe Use of Tower Cranes);

(b) a Competent Examiner[7] to carry out pre-delivery check of the tower crane before the tower crane is delivered to the workplace, completion of erection check, safe working load check, a pre-delivery check of the critical parts of the derrick crane where a derrick crane is used to erect or dismantle a tower crane (see Sections 10.7.1 and 10.15 and 10.19 of the CoP for Safe Use of Tower Cranes), etc., and certification upon erection of the tower crane; and

(c) a Safety Supervision Personnel[8] or an ICE to certify siting of crane, assessment of maximum loads and design of foundations, supporting structures and ancillary details, design and construction of the connections between the crane and the building works affected, design and construction of the foundation of the crane, and the assemblies for transferring the load from the crane onto the supporting structure, provision of an adequately designed and braced anchorage, and design and construction of the supporting structure of the derrick crane, if applicable.

There are three teams with distinct responsibilities engaged by the Specialist Contractor for the lifting operation: *Erection, Dismantling and Height Alteration Team (herein called Erection Team); Lifting Team and Inspection, Examination and Testing Team.*

In the *Erection Team*, a Competent Person and competent workmen are engaged.

In the *Lifting Team*, a lifting crew under the supervision of a Competent Person is responsible. The lifting crew is led by a Lifting Safety Supervisor, and consists of a Crane Operator, Rigger and Signaller.

In the *Inspection, Examination and Testing Team*, a competent person and competent examiner are engaged to carry out inspection, and test and examination respectively, in compliance with Regulations 5, 7A, 7B, 7E and 7G of the LALGR. A summary of the requirements for testing, thorough examination and inspection of the cranes and lifting gear under the LALGR is given in Appendices B and C.

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[6] The Supervising Engineer should have an engineering degree of relevant discipline or an engineer with the qualification of RPE/ MHKIE or equivalent; and not less than 4 years of related working experience (1 year of related working experience means 1 erection, 4 telescoping/ climbing and 1 dismantling in 12 months).

[7] The Competent Examiner should be a RPE(Mechanical Engineering or Naval Architecture & Marine).

[8] For building works and street works, the Safety Supervision Personnel means the TCP of grade T5 who possesses the academic or professional qualifications and experience of building works or street works that satisfy the requirements set out in the CoP for Site Supervision 2009 (BD, 2021); 2021); or the person responsible for engineering safety supervision as specified in the works project(s) of the government departments. For other industrial undertakings, it means a registered professional engineer in structural discipline.

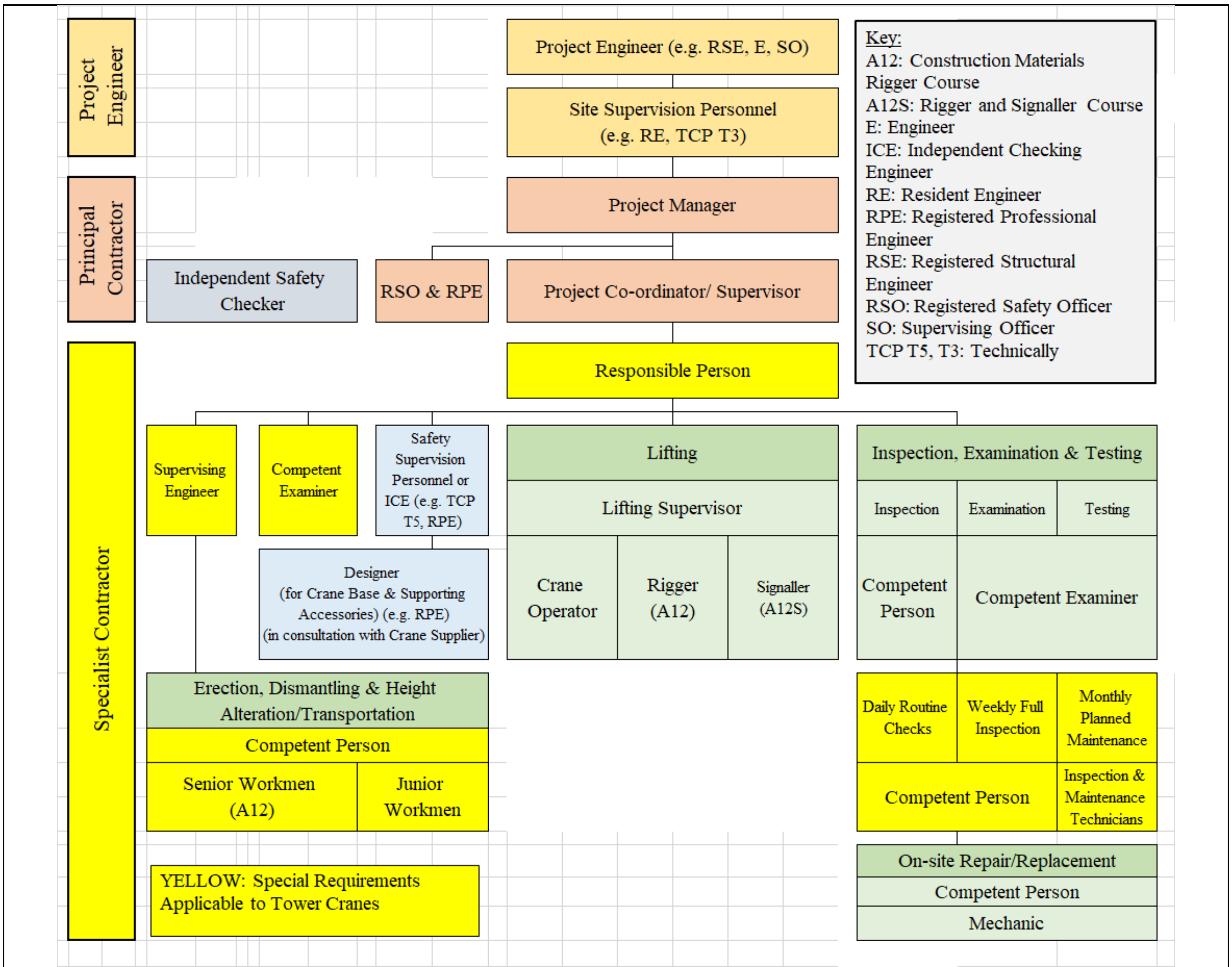
2.3 Additional Requirements for Tower Cranes

For tower cranes, for thorough planning to mitigate the potential risks, the following additional requirements are specified:

(a) The Principal Contractor and Specialist Contractor should jointly prepare a method statement in Chinese to define the procedures of the tower crane operation.

(b) The competent person and workmen working on the erection, dismantling and height alteration must have the required qualification and experience, as specified in Appendix D.

(c) There are three levels of inspection and maintenance for tower cranes: daily checks, weekly checks, and monthly checks. Routine daily checks of the crane are conducted at the beginning of each shift or working day by the crane operator, if competent, or a competent person. A full inspection is carried out at least once a week by a competent person. The crane is inspected and maintained at least once a month by the Inspection and Maintenance Technicians.



Notes:
1. The Safety Supervision Personnel or ICE and the Designer could well be employed by the Principal Contractor to provide the services.
2. An Independent Safety Checker may be engaged to carry out site safety audit in respect of the lifting operation.

Figure 1 – Parties Involved in Lifting Operation

3. PLANNING OF LIFTING OPERATION

3.1 Safe System of Work

The Principal Contractor will establish a safe system of work for the lifting operation. The safe system of work is a formal procedure established after examining the task systematically, and identifying all the hazards associated with the task (LD, 2004). The safe system of work for the lifting operation should include, but not be limited to, the following (LD, 2011; LD, 2017b):

(a) task-specific risk assessment;
(b) planning of the operation;
(c) selection, provision and use of a suitable crane and equipment;
(d) maintenance, examination and testing of the crane and equipment;
(e) provision of a log-book for the competent examiner/competent person/mechanic to enter the details of testing, examination, inspection, maintenance/repair works which have been carried out for the crane;
(f) implementation of a permit-to-work system (commonly known as Permit-to-Lift);
(g) provision of properly trained and competent personnel who have been made aware of their relevant responsibilities under Sections 6A and 6B of the FIUO;
(h) adequate supervision by properly trained and competent personnel;
(i) observing for any unsafe conditions, such as adverse weather conditions that may arise during operation;
(j) ensuring that all necessary test and examination certificates and other documents are available;
(k) preventing unauthorized movement or use of the crane at all times;
(l) safety of other persons who may be affected by the lifting operation; and
(m) contingency plan providing procedures to be followed in case of emergency situation.

In this regard, the Project Manager of the Principal Contractor or his delegate will oversee the implementation of the safe system of work.

3.2 Task-specific Risk Assessment

The RSO of the Principal Contractor will develop a task-specific risk assessment for the lifting operation prior to the works. The risk assessment aims to identify the hazards inherent in the processes, as well as those from adjacent activities, and then devise measures to avoid those hazards. Where the risks are significant, appropriate safety measures should be put in place to eliminate or reduce the risks. Based on the risk assessment, suitable method statements for the lifting operation should be developed.

A report for the risk assessment should consist of the following sections, as recommended in CIC (2010):

(a) introduction;
(b) hazard assessment;
(c) method statement;
(d) personal particulars of crew members; and
(e) manufacturer’s manual.

The details that should be covered in each respective section of the report for risk assessment are given in Appendix E.

3.3 Lifting Plan

The Principal Contractor will work with the Specialist Contractor to decide on the type of crane used, crane location, crane base, crane erection and dismantling, etc., and develop a lifting plan for the project. The following details, among others, should be included in the lifting plan:

(a) details of loads lifted, including dimensions, weight, sizes, shapes, etc.;
(b) lifting methods;
(c) type of crane (lifting capacity, radius, reach);
(d) crane position, including impact on surroundings (if any), a layout plan of the lifting zone (Figure 2) (showing position of crane and lifting personnel, unloading and installation points of loads, path of movement of jib, restricted areas for lifting, etc.);
(e) crane base (type and additional support); and
(f) crane erection (type of mobile crane and slave) and dismantling (space and impact on surroundings).

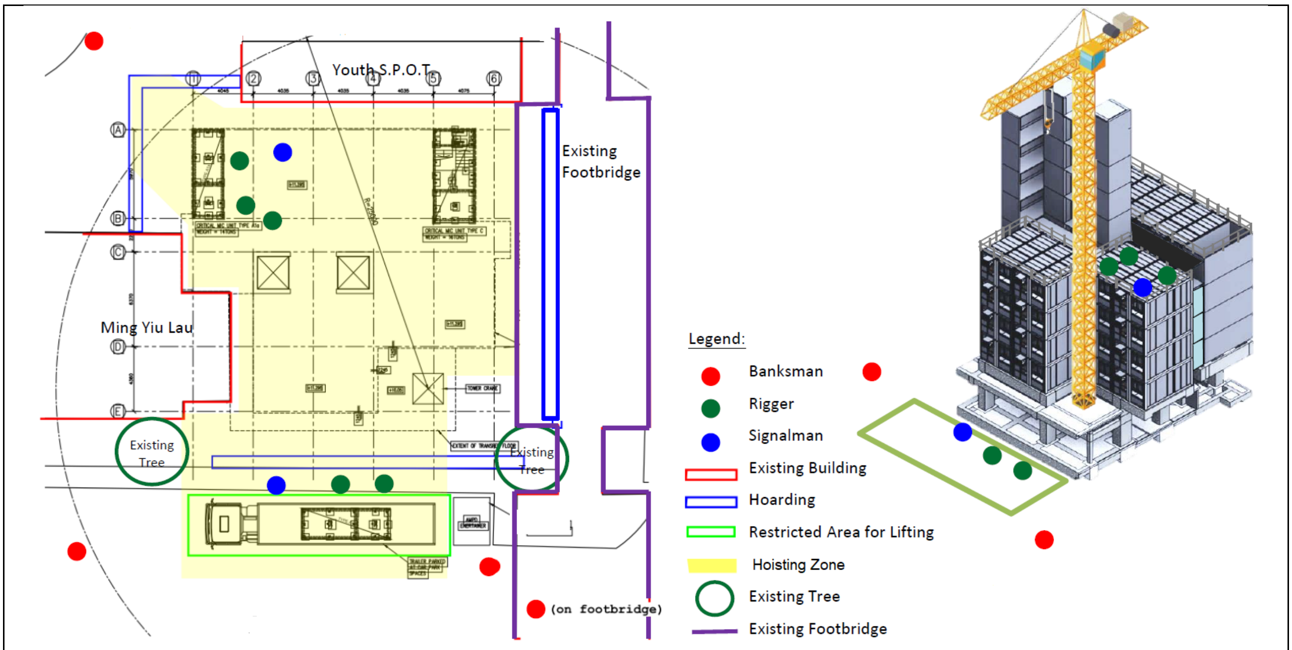


Figure 2 – Example of Layout Plan for Lifting Plan (After HKHS (2022)[9])

A *hoisting zone*, which is defined as a dedicated fatal zone earmarked for lifting of materials to control the risk of lifting operation and falling objects in a controlled environment, should be clearly defined in the lifting plan. The zone should be effectively barricaded during the crane movement and lifting operation.

[9] HKHS (2022). Risk Management Workshop-Heavy Lifting for Development of Purpose-Built Elderly Flats with MiC For Jat Min Chuen, Shatin, 10 October 2022.

4. LIFTING METHODS

4.1 Lifting History of Modules

MiC modules are subject to a number of liftings during their life time. During manufacture, the incomplete modules are subject to incidental lifts in the prefabrication factory. Upon completion, they will be lifted at the following occasions (Monash University, 2017):

(a) removal from prefabrication factory to storage while awaiting delivery to building site (two lifts may be involved);
(b) loading onto road transport;
(c) loading onto and unloading from marine transport (if marine transport is used);
(d) erection at building site; and
(e) eventual demolition (if applicable).

For MiC projects with an intended service life, such as the transitional social housing projects, MiC modules may be subject to further lifting for dismantling and re-erection.

4.2 Lifting Frame

Lifting is normally carried out from the top of MiC modules. Some typical lifting gear used for lifting of MiC modules are shown in Figure 3. The gear normally includes master link, chain slings (lifting cable), shackle, lifting frame and block chain.

Lifting Gear Summary for MiC Module

Item	Description	S.W.L. (tons)	Length	Quantity
1	Master Link	35	N/A	1
2	4 Legs Chain Sling	20	6m	1
3	Shackle	12	N/A	8
4	Shackle	8.5	N/A	8
5	Lifting Frame	N/A	N/A	1
6	Chain Sling	10	2m	2
7	Block Chain	5	3m	2
8	Block Chain	2	3m	2

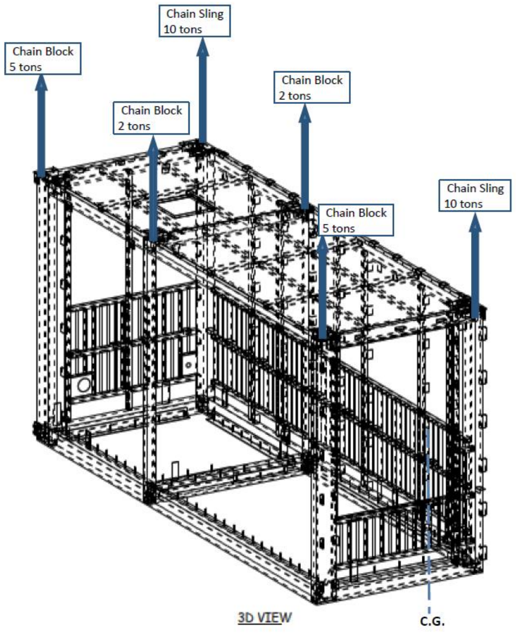


Figure 3 – Typical Lifting Gear Used for Lifting of MiC Module[9]

The chain sling is attached to the modules at the specific lifting points of the modules, as shown in Figure 4.

The three grades of chain sling that are normally used in overhead lifting are Grades 8, 10 and 12, among which Grade 12 chain sling has the strongest tensile strength. A summary of the properties of the different grades of chain sling used is given in Appendix F.

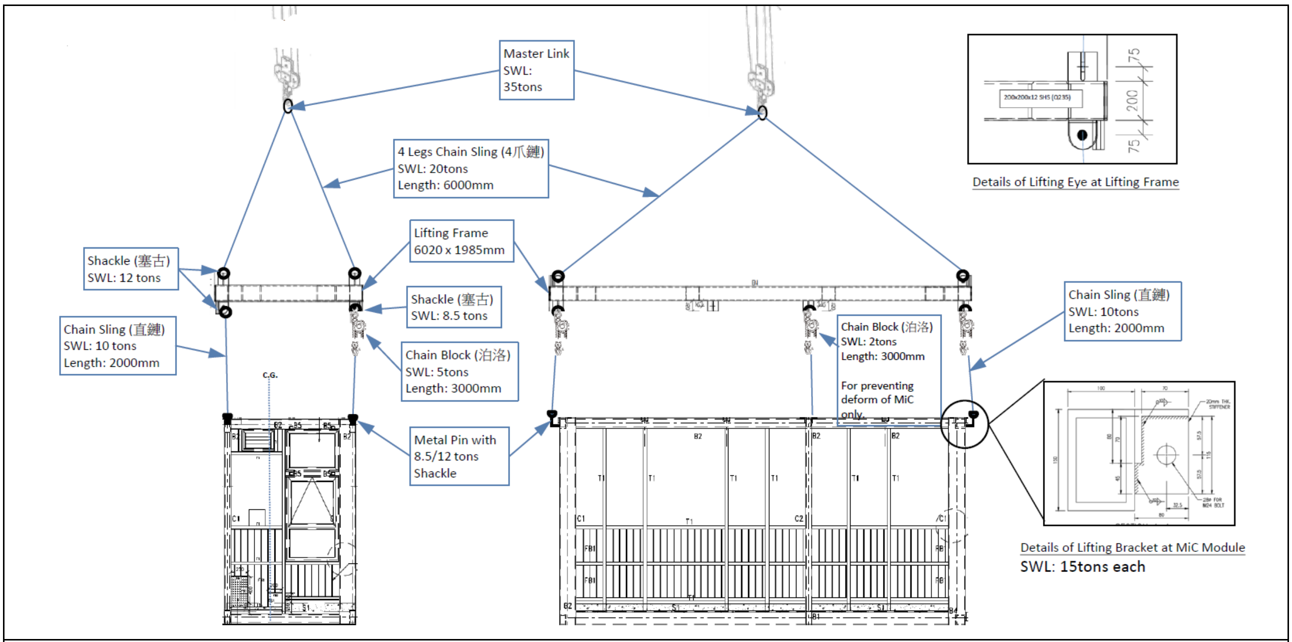


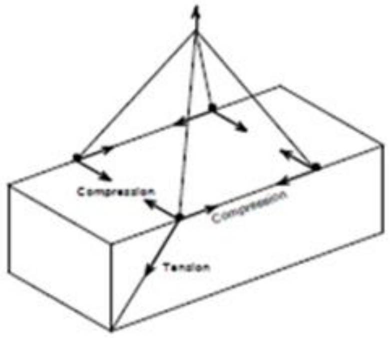
Figure 4 – Typical Lifting Arrangement for a MiC Module[9]

Lifting can be carried out from one point, or using a cross-beam or lifting frame, as shown in Figure 5.

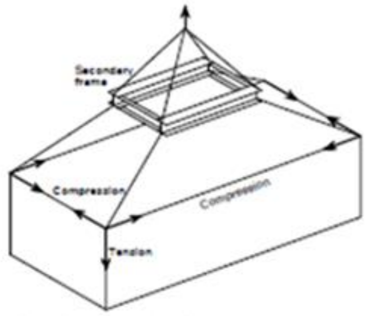
(a) Lifting from One Point | (b) Lifting from a Cross-beam | (c) Lifting from a Lifting Frame

Figure 5 – Views of Different Techniques of Lifting Modules

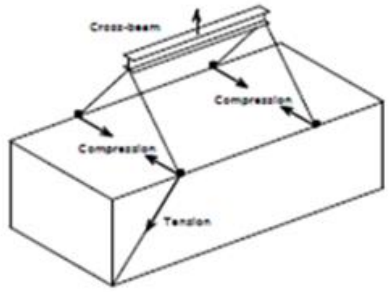
Depending on the location of the lifting points, sling angle and lifting method used, compressive and tensile forces are induced on the modules, as shown in Figure 6. There are forces acting on the module when a module is lifted from one point, or from a secondary frame or cross-beam (Figures 6(a) to (c)). The forces induced become negligible when a lifting frame equal to the plan dimensions of the module is used, as shown in Figure 6(d).



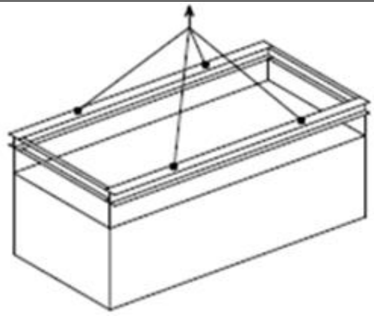
(a) Lifting from One Point



(b) Lifting from Secondary Frame



(c) Lifting from a Cross-beam



(d) Lifting from a Lifting Frame

Figure 6 – Different Techniques of Lifting Modules

A designer competent in structural engineering and lifting should be engaged in the lifting frame design. He/she should check that all the intended lifting activities (both in prefabrication factory and on-site), as described in Section 4.1, have been designed for, and the rigging practices incorporated where suitable.

To determine the locations of the lifting points, size and angle of sling, and size and configuration of the lifting frame in the design, the following should be assessed for every lifting activity:

(a) weight, dimensions and centre of gravity of the modules lifted;
(b) relevant information including lifting weight and design capacity of lifting insert specified on the plans approved by BD;
(c) pick-up and set-down conditions of the modules (including any requirement for re-orientation), capacity of crane set-up area, rigging configuration;
(d) module stability and support conditions for the completion of the lift (e.g. connections, temporary bracing);
(e) rigging configuration, in particular when angled slings are used (note: use of angled slings will transfer additional axial compression loads onto the modules, and appropriate design of the lifting spreader is needed);
(f) static load distribution between multiple slings; and
(g) works sequence involving installation of modules close to others, accounting for working space, temporary works clearances and the required connections (Note: The installation sequence shown on the plans approved by BD should be followed.).

A check of the structural integrity of the modules to withstand the forces induced on them, and the tolerance of the modules to distortion during lifting should be made, particularly for cases when angled slings are used. The age and/or strength of concrete for lifting / installation specified on the plans approved by BD (if applicable) should be complied with. The potential behaviour of the modules and the ductility of the materials when they are overloaded should be checked. A contingency plan should be put in place to cover the situation when the lifting cannot be completed as intended, and the modules have to be laid down elsewhere.

Attention should be given to the wind speed during lifting. As a reference, lifting of modules which have a wind exposed surface area larger than 20 m^2, should not proceed when the wind speed exceeds 54 km/hr.

5. TOWER CRANES

5.1 General

In the sections that follow, a description of the tower crane key components and crane type is given, followed by a discussion of the considerations for the safe use of tower cranes in the areas of crane selection, siting of tower crane, crane base design, crane height alteration and dismantling, and safety operation measures.

The lifting capacity of a tower crane depends on the distance that the jib can reach. Hence, it is more appropriate to describe the lifting capacity of a tower crane, in terms of the jib-end capacity (i.e. the lifting capacity at the maximum reach of the hook block from the centre of the tower mast), as shown in Figure 7.

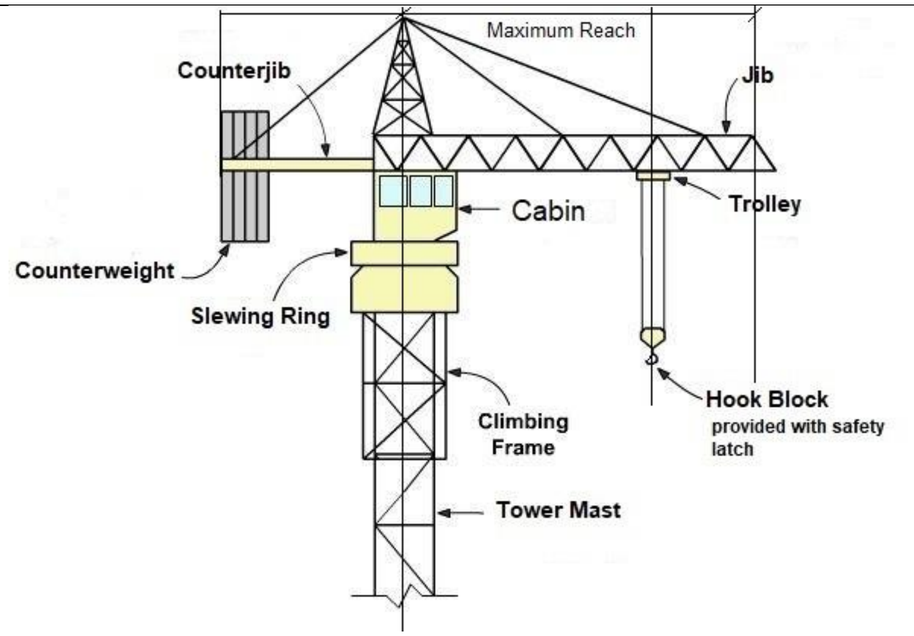


Figure 7 – Key Components of a Tower Crane

5.2 Crane Key Components and Sensors

The key components of a tower crane is included in Figure 7. A tower crane consists of a tower mast, slewing ring, cabin, jib and counterjib, trolley and hook block, counterweight, etc. A brief description of the key components is given below:

(a) Tower mast. The tower mast is the vertical portion of the crane that extends upward from the ground. It supports the cabin, hook block and counterweights as they rotate around it.

(a) Slewing ring. This is a turn table that allows the top of the crane to rotate and serves as a base for the cabin.

(b) Cabin. It is a glass box on the side or underside of the mast where the crane operator sits.

(c) Jib and counterjib. The jib and counterjib are the steel lattice that extend out horizontally from the top of the mast. The jib carries the trolley, hook block and load of the crane, whereas the counterjib is used to offset the weight of the jib and hold the counterweights in place. Counterweights are placed at the end of the counterjib.

(d) Trolley and hook block. The trolley moves back and forth along the jib as needed to place the hook on top of the loads requiring lifting. The hook block is a pulley system which goes up and down.

Tower cranes are normally built and operated near residential area, so it is necessary that tower cranes are operated in a safe and secure manner to protect workers on-site and nearby properties. To ensure safe operation, sensors are installed in a tower crane to collect data on wind speed, load, slewing angle, hook height, radius, etc., in real time to ensure safe operation, as shown in Figure 8. The data are displayed on a monitor and transferred to an application server, which stores, computes, analyzes and monitors the data collected, and sends alarm message to on-site workers and relevant parties, for appropriate action, as needed.

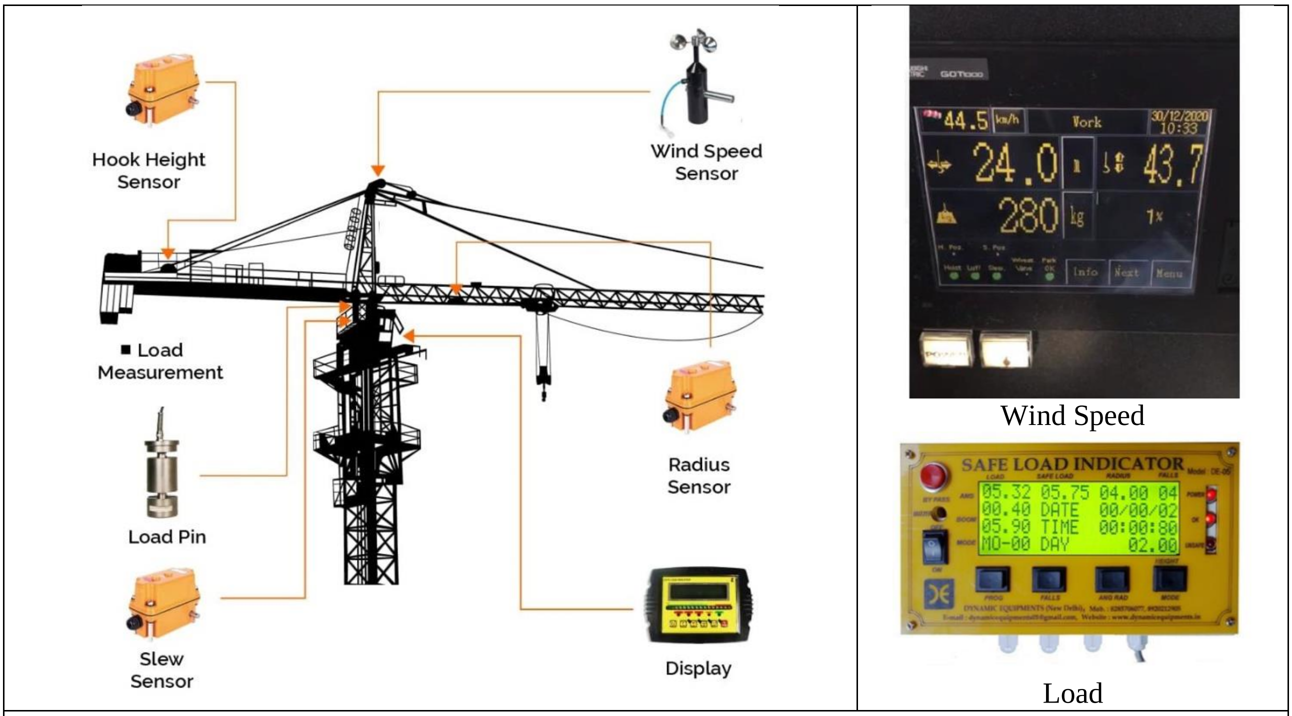


Figure 8 – Sensors Installed in Tower Crane

A typical display of the wind speed sensor and an automatic safe load indicator (ASLI)[10] is included in Figure 8. Cranes are generally designed to operate under a wind speed up to 54 km/hr. An audible and visible warning will be triggered to alert the crane operator when the wind speed exceed 54 km/hr. The crane operator will release the jib brake to allow the jib rotate freely under the strong wind condition. Installation of an ASLI is mandatory for all tower cranes (Regulation 7B of the LALGR (Cap. 59J)), except for those with a maximum SWL of 1 tonne or less or those operating with a grab or any electromagnetic means. The device should be able to give an audible and visible warning to the operator when the crane is approaching its SWL, and give a further audible and visible

[10] An automatic safe load indicator (ASLI) is a device installed in the crane to alert the operator when the lift is approaching and has exceeded the safe working load of the machinery.

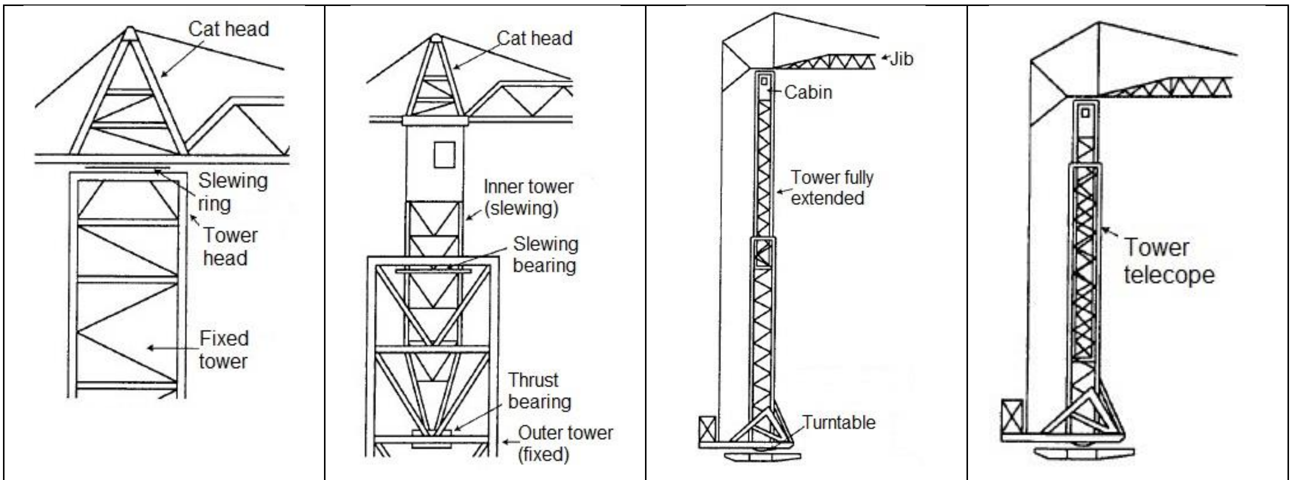
warning when the crane has exceeded its SWL. The specification of an ASLI should conform to British Standard 7262 or equivalent standards.

5.3 Crane Type

5.3.1 Tower Configuration

In terms of *tower configuration*, tower cranes are available with fixed or slewing towers, as shown in Figure 9. In the fixed tower type, the slewing ring is situated at or near the top of the tower and the jib slews in a horizontal plane about the vertical axle of the stationary tower. In the slewing tower type, the slewing ring is situated at the bottom of the tower and the whole of the tower and jib assembly slews relative to the base of the crane.

The tower that supports the jib can be a mono tower, inner and outer tower and telescopic tower. In mono tower (Figure 9(a)), the jib is carried by a single tower structure, whereas in inner and outer tower (Figure 9(b)), the jib is supported by a fixed outer tower. The tower can be extended in both of these two tower types. In telescopic tower (Figure 9(c)), the tower structure consists of two or more main sections which nest into each other to enable the height of the crane to be altered using hydraulic rams without the need for partial dismantling and re-erection. The hydraulic system used should be properly tested in accordance with the manufacturer's recommendations before it is used in each operation.



(a) Mono Tower | (b) Inner and Outer Tower | (c) Telescopic Tower

Figure 9 – Types of Tower Cranes in Terms of Tower Configuration (after LD (2011))

5.3.2 Jib Configuration

In terms of *jib configuration*, the three main types of tower cranes are flat-top, hammerhead and luffing, as shown in Figure 10. Tower cranes of other jib types are also available, such as fixed luffing jib, rear pivoted luffing jib and articulated jib, but they are not commonly used.

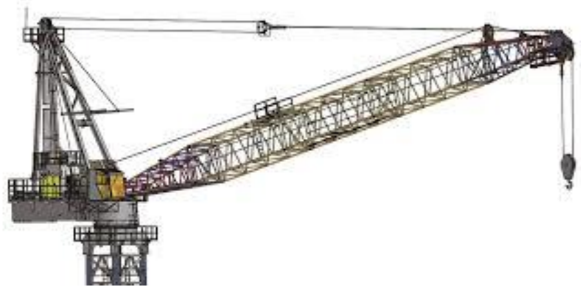
Flat-top tower cranes have no vertical apex and they are provided with a jib and counterjib only. This makes flat-top cranes a good choice for sites where there is height restriction. This type of crane is good for congested works sites or sites where cranes need to overlap.

Hammerhead tower cranes have a vertical apex and a horizontal jib which supports the cabin. With this type of crane, the horizontal movement of the load at specific height can be controlled more precisely. Hammerhead tower crane is considered the most efficient type of crane with a long working life and a wide range of capacity. The transportation cost is low, and the setting-up time is fast and easy.

Luffing means movement of the jib of a crane vertically to lift a load. Luffing tower cranes have a diagonal arm extending out from the top of the mast at an angle. The diagonal arm moves in and out (from vertical to a 15° angle). This movement allows luffing tower cranes to fit within tight spaces. The slewing radius of luffing tower cranes is much smaller than that of flat-top and hammerhead tower cranes. This makes luffing tower cranes more suitable for downtown congested work sites or sites where there are two or more cranes working at the same time. This type of crane is designed for high building project, and is good for working in extremely restricted spaces.

(a) Flat-top[11]

(b) Hammerhead



(c) Luffing

Figure 10 – Types of Tower Cranes in Terms of Jib Configuration

5.3.3 <u>Mounting Configuration</u>

In terms of *mounting configuration*, tower cranes are constructed on static bases, or mounted on rail units or mobile units.

Three types of static bases are normally used: in-situ base, on-own case and climbing base, as shown in Figure 11. In the in-situ base (Figure 11(a)), the crane is mounted on special corner angles, frames or an expandable tower section, which are cast into the concrete foundation block or pile cap of the building, as the building is constructed. In the on-own base (Figure 11(b)), the crane is mounted

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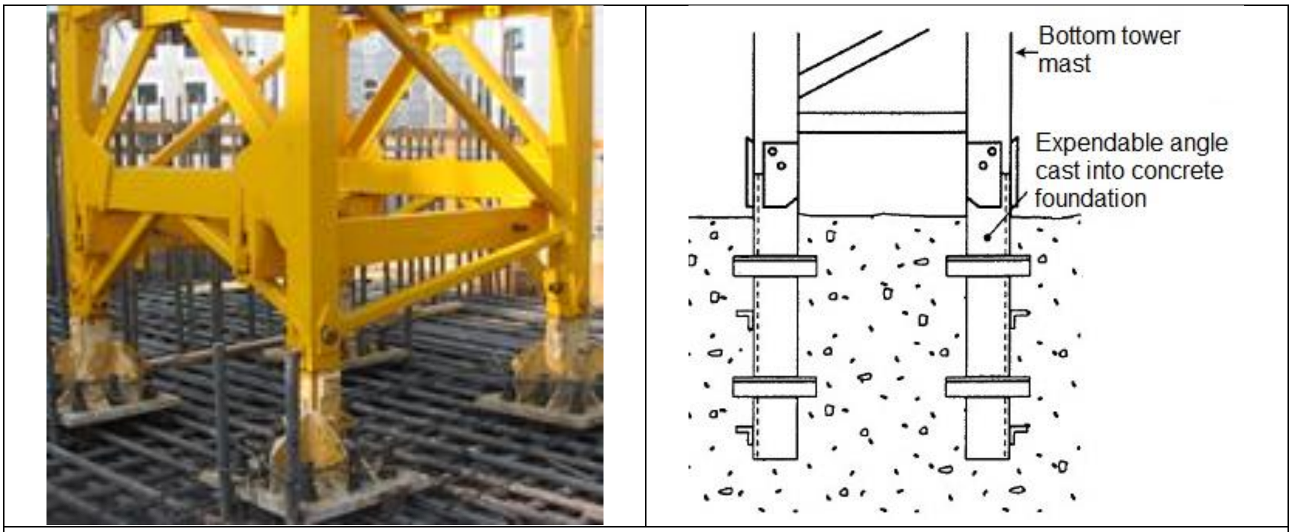
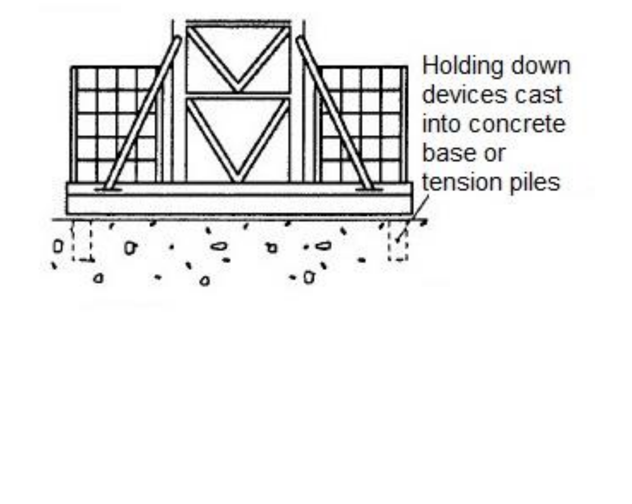
11 http://en.zoomlion.com/channel/9b442fdb031345b59cb3ca24da55b137.html?type=3&isChannel=0&isSelect=1&typeId=b0f833bdc7d145f2a525cf53eb4087c7

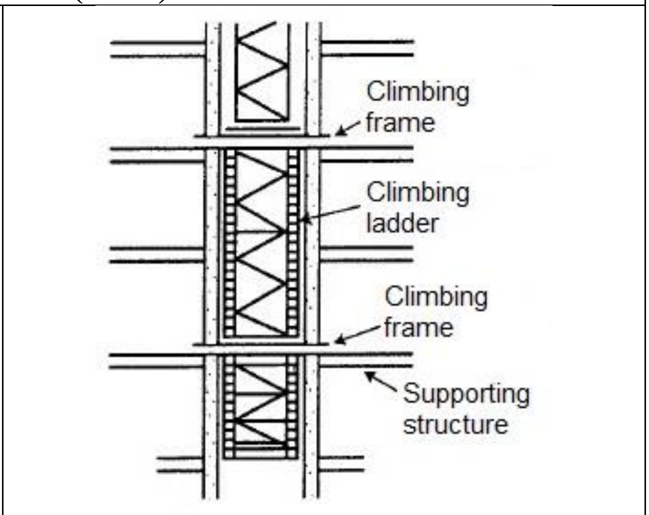
on its own base section or chassis which sits on a concrete base with ballast. In the climbing base (Figure 11(c)), the crane is supported by a structure which is being constructed, and to which climbing frames and wedges are attached. The height of the crane is extended by means of climbing supports attached to the frames, as the structure is constructed. Metal ladders, rods or tubes can be used as climbing support. A climbing crane may be mounted initially on a fixed base and its support can be transferred to climbing frames and supports later.



(a) Static Base (in-situ)



(b) On-own Base



(c) Climbing Base

Figure 11 – Types of Cranes in Terms of Mounting Configuration (after LD (2011))

5.4 Crane Selection

In the selection of cranes, the following should be considered:

(a) Carrying capacity. The carrying capacity is the maximum load that the crane will be used under the specified conditions. Every crane has a set capacity that it can hoist within a given radius of that crane. The capacity of the crane depends on a number of factors, such as configurations of tower, jib and mounting, crane location, crane base design, wind and impact loading and the need for rapid swinging. These factors should be considered during the planning stage of the lifting operation. It is important that instead of fixing a safety margin for the crane (e.g. not exceeding 85%, 90%, 95% of capacity), an assessment is made before the lifting and a sufficient safety margin for the lifting capacity is included (see Figure 12). This will help establish suitable crane's specifications. Appropriate optimization arrangements should be made according to the actual situation on-site.

The maximum weight of the modules for the project is usually shown on the plans approved by BD. The load carrying profile over the jib length should be identified so that the correct type of crane with its specifications can be selected.

(b) Maximum coverage. The jib length should be chosen to reach the furthest point of delivery of modules. It should be noted that use of excessive length will result in the jib being under-utilized and the safety of the public jeopardized. It is also not cost-effective because it costs more to buy or rent a longer-jib crane.

(c) Sufficient space for assembly, erection and dismantling of crane. There should be enough space allocated for assembly, erection and dismantling of the crane selected. The components delivered to site must be reachable by a mobile crane/derrick crane used to erect the tower crane. Space for staging and assembly of components is also required. Access must be provided for the mobile crane/derrick crane to dismantle the tower crane. If the crane is designed to climb down by itself, enough clearance between the crane and adjacent building should be provided.

(d) Ability to slew/luff freely. The crane should be able to turn 360^o freely without any obstruction. For luffing crane, the crane must be able to luff vertically especially for congested sites surrounded by existing buildings.

(e) Height of tower crane. The crane should be high enough to deliver the modules to the points where they will be installed. It should be higher than adjacent buildings or the height of the tallest crane over which the jib passes.

(f) Overall construction sequence. The construction sequence shown on the plans approved by BD should cover construction of the in-situ structure portion and its relationship with installation of MiC modules (e.g. details of the in-situ structure, whether wholly or in terms of the number of storeys completed, before installation of MiC modules). The specified sequence may affect the site planning when the mounting type of crane is adopted.

The type of the tower crane used can be established from the tower crane database, which contains details of tower crane model, radius of jib, lifting capacity characteristics, hook height, etc.

In some database, rental fees, and technical details of the tower cranes, including slewing velocity, horizontal speed of hook block along the jib, hoisting speed of hook block, etc., are included. With the rental fees, a cost comparison between different models of tower cranes, when more than one models are found suitable, can be made. These details allow an evaluation of the time taken for transporting modules from the lifting point to the installation point, and hence the operating cost, transportation time, duration of construction process, etc.

In crane selection, safety should be considered in the first place. In addition to the price of the crane, other factors, such as the company's financial status, and size, duration and type of project should also be considered.

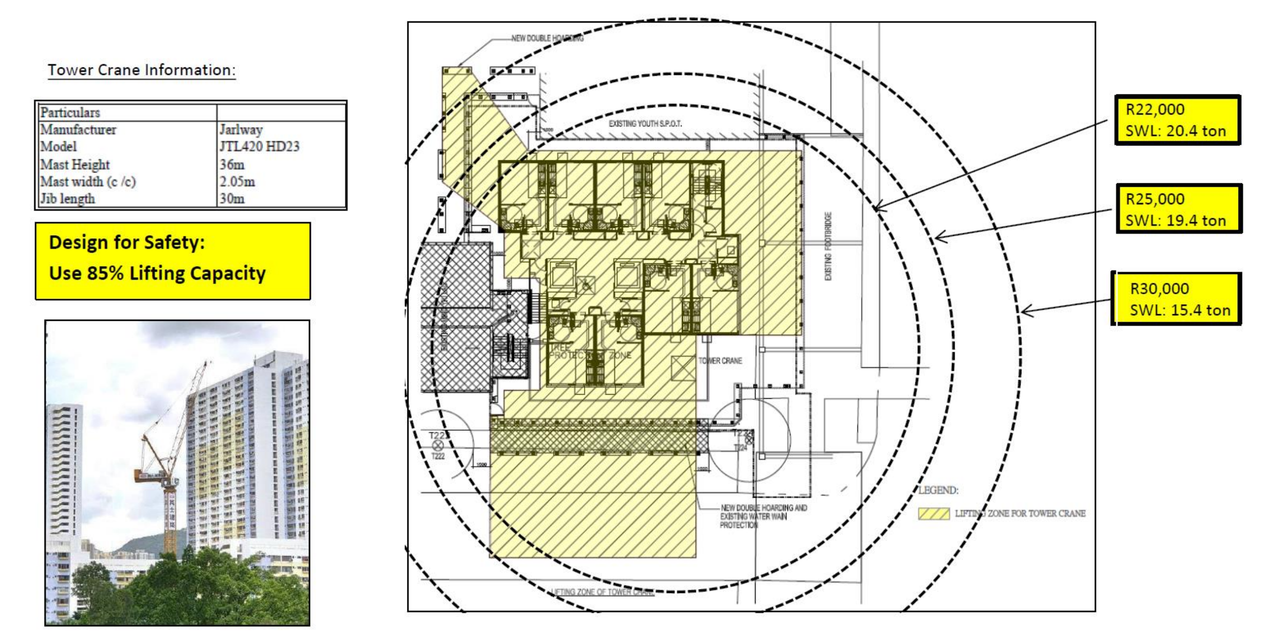


Figure 12 – Consideration for Tower Crane Selection[9]

5.5 Siting of Crane

Establishing the crane location in a site is important in a MiC project. MiC modules are heavy and cannot be moved around easily. The operational efficiency of a crane will be reduced if it cannot reach out to the required points to pick-up and unload the modules.

In deciding on the crane location, the following should be considered:

(a) site layout (so that no part of the crane would project outside the site boundary);
(b) building layout and height;
(c) maximum coverage (heights of lift and distances/areas of movement of loads, i.e. lifting locations and destination of loads);
(d) weights and dimensions of loads;
(e) number and frequency of lifts;
(f) length of time for which the crane will be required;
(g) operational time (hour per week);
(h) follow-up making good work after removal of crane, e.g. concreting the floor opening for crane sitting inside floor plate;
(i) workplace conditions, including ground conditions for crane standing, and space available for crane access, erection, operation and dismantling;
(j) construction and installation sequence of MiC modules; and
(k) any special operational requirements or limitations imposed including the existence of other cranes in close proximity.

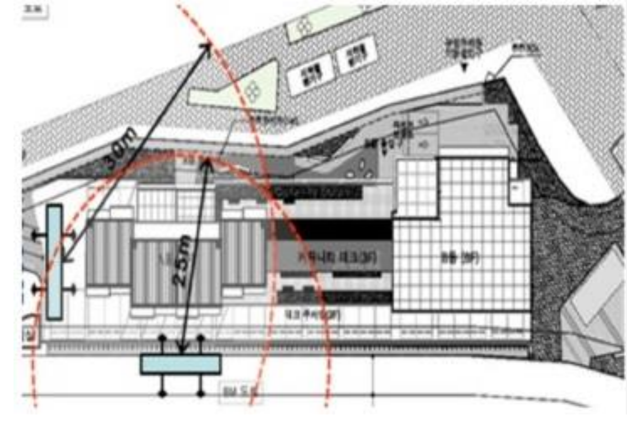
A number of optimization methods can be used to determine the tower crane location, e.g. mixed-integer linear programming (Sangaiah, et. al., 2019; Meng, et. al., 2020), ant colony optimization (Trevino, 2017), particle swarm optimization (Adrain, et. al., 2014), colliding bodies optimization (Kaveh & Mahdavi, 2014), genetic algorithm (Golberg, 1989; Tam, et. al., 2001), etc. The following steps are involved in the assessment, as shown in Figure 13:

(a) prepare a site and building layout plan, as shown in Figures 10(a) and (b) (Notes: Depending on the size of the site, the site arrangement and road conditions nearby, MiC modules may be lifted from the trailers driven into the site or parked outside the site. The carriageway within the site and the roads outside the site should be included in the layout plan. To facilitate easy movement of trailers inside the site, a gantry wider than 7.5 m for entry and exit is recommended. For lifting of modules outside the site, traffic impacts should have been assessed and approved, and temporary traffic management measures should be in place. The areas of no module installation, and the restricted areas for siting the tower crane and parking the trailers should be marked in the plan.);

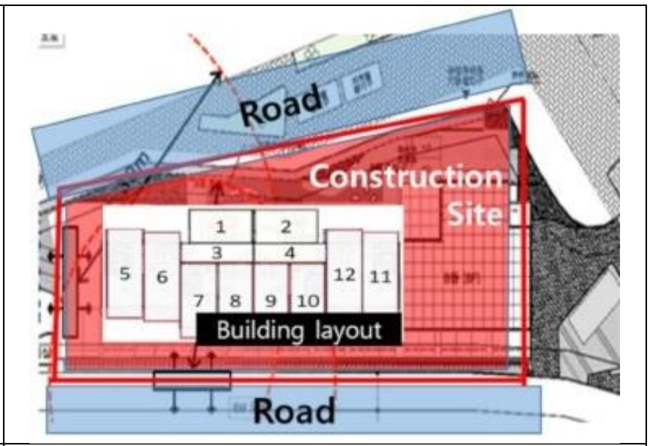
(b) establish the x-y co-ordinates for the features, including the tower crane, and module to be lifted (Notes: A 0.5 m grid is recommended.) (Figure 13(c)); and

(c) establish the distances between the tower crane and the module to be lifted, and between the tower crane and the module to be installed in terms of x-y co-ordinates.

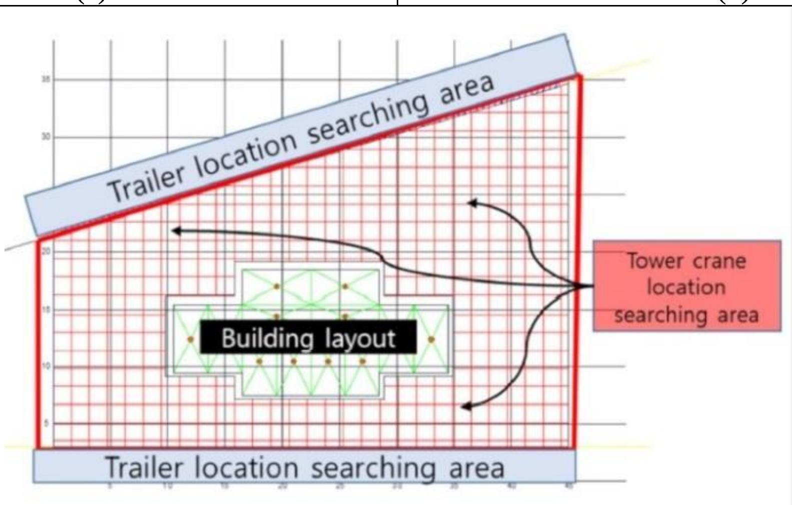
Based on the distances established, the greatest distances between the tower crane and the trailer location where the modules will be lifted, and between the tower crane and the installation location where the modules will be placed are determined. The greatest distances are then minimized to get the optimal location of the tower crane (i.e. m*in. [max. distance {tower crane, trailer location}, max. distance {tower crane, installation locations}]).*



13(a)



13(b)



13(c)

Figure 13 – Establishing the Optimal Tower Crane Location (after Hyun et al (2021))

5.6 Crane Base Design

Providing a properly designed foundation to a tower crane is important. For tower cranes, though different forms of crane base are available, the in-situ base is often used (see Figure 11(a)). Pile foundations may be used for the in-situ base, but the usual practice is to mount the tower mast legs to the special corners or frames casted in the concrete foundation block (e.g. base slab, pile cap, etc.) of the building as discussed in Section 5.3.3. This is a win-win situation to use the concrete foundation block (e.g. base slab, pile cap, etc.) of the building to work as foundation of the tower crane. In this case, constructing a separate foundation for the tower crane is not needed, and a substantial cost and time saving will result.

The crane base design should comply with the relevant Codes of Practice in Hong Kong.

The loads acting on the in-situ base depend on the crane type and crane configuration e.g. jib length, crane height, crane capacity, leg dimensions and spacing.

Once the crane type and crane configuration have been decided, the load parameters applicable to the tower crane should be provided by its manufacturer, which can be obtained from the crane supplier. The load parameters for a typical tower crane for foundation analysis is given in Figure 14(a), for the leg dimensions and spacing of the crane shown in Figure 14(b). Two sets of load parameters are provided:

(a) in-service loads[12] (i.e. when the crane is operational); and
(b) out-of service loads[13] (i.e. when the crane is at rest).

The crane is designed to be free-standing to ensure that the loads and moments are taken by the foundation.

The loads acting on the in-situ base include moment (M), vertical force (V,) horizontal force (H) and twisting moment (Mt), as shown in Figure 14(c). There is twisting moment (Mt) under in-service loading condition only.

Most cranes are based on European wind code in determining the out-of-service loads. Hence, adjustments to the moment (M) and horizontal force (H) need to be made to account for the wind load conditions in Hong Kong. Reference is made to the crane supplier's datasheet and the CoP on Wind Effects in Hong Kong 2019 (BD (2019)) in evaluating the out-of-service wind loads acting on the crane (see clause 2.2 on wind forces in the CoP on Wind Effects in Hong Kong 2019, etc.). Tower cranes are normally designed as temporary structures remaining in position for a period of not more than 1 year, so the wind loads may be designed as a minimum of 70% of the design for permanent structures (see clause 2.5 on minimum wind loads for temporary structures in the CoP on Wind Effects in Hong Kong 2019).

The factored load parameters taking into consideration of the wind forces in Hong Kong, load factor, temporary structure factor, etc., are included in Figure 14(a).

Using the factored load parameters established, the forces acting on the tower mast legs at eight critical jib positions, as those shown in Figure 14(d), are evaluated, under the in-service and out-of-service loading conditions. The forces established from the evaluation are shown in Figure 14(e). It can be seen that the crane base design is governed by the out-of-service loads in this case. Using the maximum tensile force obtained, holding down bolts are designed, as shown in Figure 14(f). The bolts are installed in the concrete foundation block, prior to concreting.

The following design checks are carried out, including but not limited to: overall stability check of the crane foundation (i.e. uplift, overturning and sliding), flexural check, pull-out check[14], punching shear check[15] and crack width check[16].

For a tower crane supported on pile cap, the tension developed in any of the four legs for the critical load case must be checked and designed for properly. The uplift developed in any of the legs

[12] In-service loads include dead loads (i.e. weight of the tower crane components), imposed loads (i.e. weight of the loads lifted, including weight of the lifting gear and ropes), wind loads and dynamic loads (due to slewing, trolleying, hoisting, etc.).
[13] Out-of-service loads include dead loads and wind loads only.
[14] The resisting force developed in the crane legs anchored into the foundation should be designed to have an adequate margin of safety against the pull-out force.
[15] The base slab should be thick enough to give an adequate margin of safety against the punching failure caused by the vertical compressive force.
[16] The crack widths in the X and Y direction of the reinforcement should be reviewed for the top and bottom surface of the foundation to check that the allowable crack width for the top and bottom of the foundations is not exceeded.

must be adequately resisted by both the crane base or pile cap, as well as the piles in the latter case. Tension anchorage or piles should be installed for this purpose where necessary.

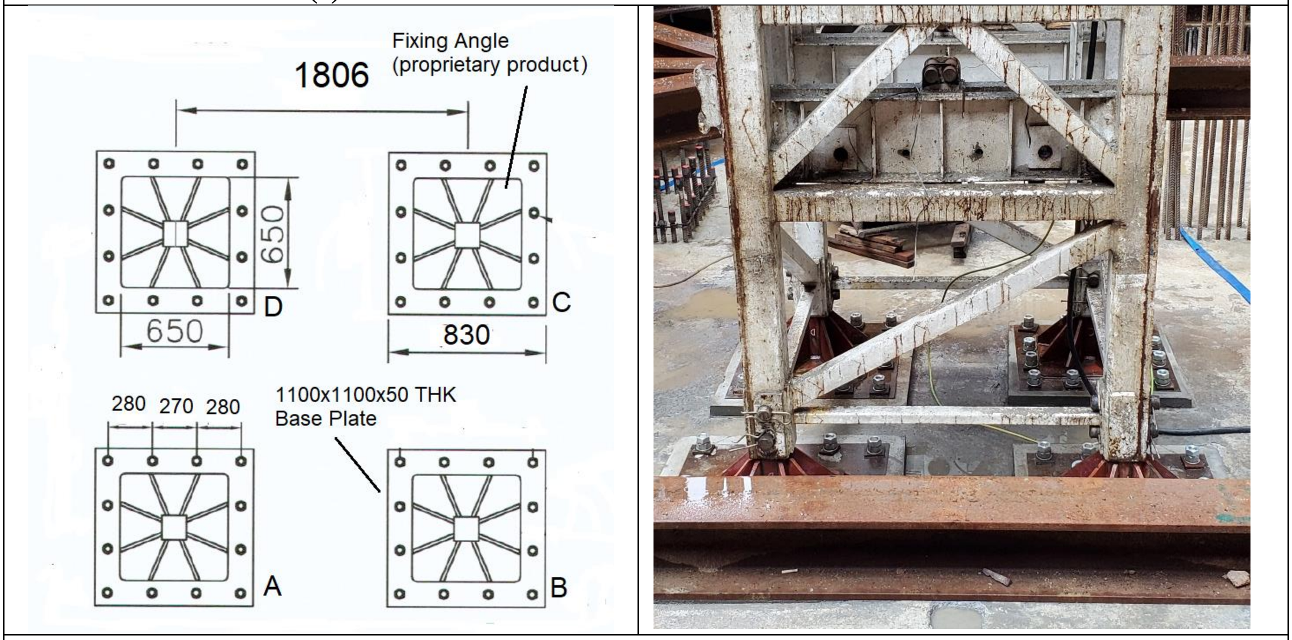
In addition to the crane base, crane tie design should also be included in the engineering design consideration.

Tower Crane Load Parameters	In-service Loads				Out-of-service Loads		
	M (kNm)	**V (kN)**	**H (kN)**	**Mt (kNm)**	**M (kNm)**	**V (kN)**	**H (kN)**
Unfactored	2923	883	22	399	2682	785	160
Factored	**4677**	**1413**	**35**	**638**	**6533**	**1099**	**390**

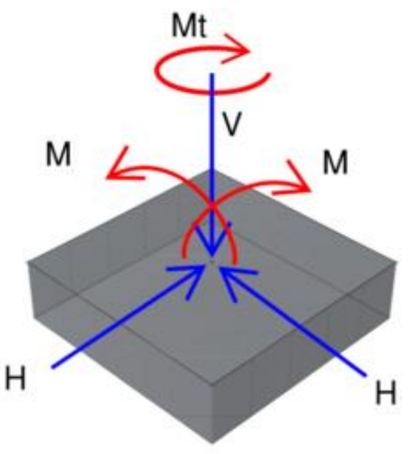
Legend: M: Moment; V: Vertical Force; H: Horizontal Force; Mt: Twisting Moment

Notes:
1. The crane load data are specific to the type of tower crane used, as a function of jib length, crane height and crane capacity, and they are provided by the crane supplier.
2. The factored load data are obtained by applying a load factor of 1.6 to M, V, H and Mt under in-service conditions, and a load factor of 1.4 to M, V and H, and an adjustment factor of 1.74 to M and H to account for wind loads under out-of-service conditions.

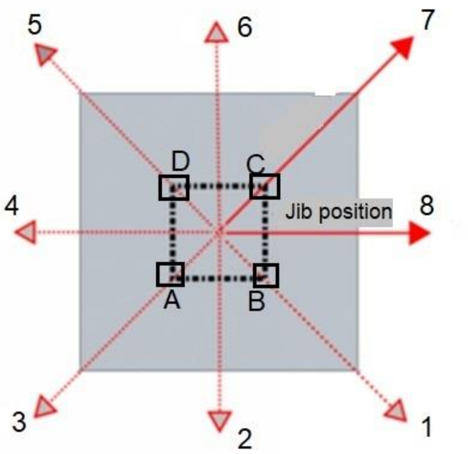
14(a) Unfactored and Factored Tower Crane Load Parameters



14(b) Dimensions and Spacing of Tower Mast Legs



14(c) Loads Acting on Crane Foundation

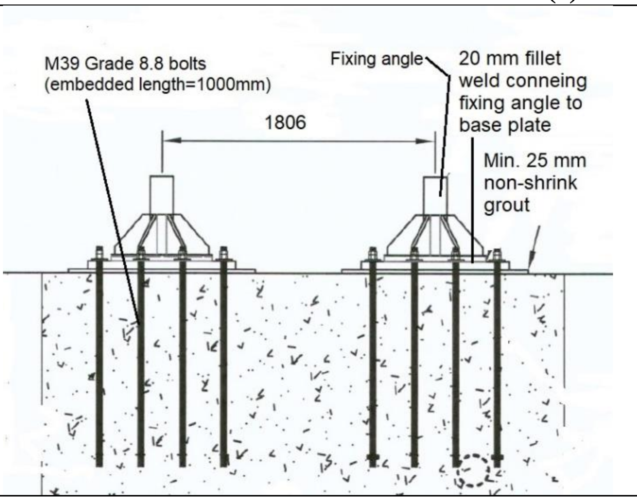


14(d) Loading Cases with Jib at Eight Critical Positions

	In-service Loads					Out-of-service Loads				
Reaction Force	RA (kN)	RB (kN)	RC (kN)	RD (kN)	HF (kN)	RA (kN)	RB (kN)	RC (kN)	RD (kN)	HF (kN)
Jib Position 1	353	**2180**	353	**-1474**	134	275	**2827**	275	**-2277**	97
Jib Position 2	1645	1645	-939	-939	134	2080	2080	-1530	-1530	97
Jib Position 3	**2180**	353	**-1474**	353	134	**2827**	275	**-2277**	275	97
Jib Position 4	1645	-939	-939	1645	134	2080	-1530	-1530	2080	97
Jib Position 5	353	**-1474**	353	**2180**	134	275	**2277**	275	**2827**	97
Jib Position 6	-939	1645	1645	-939	134	-1530	-1530	2080	2080	97
Jib Position 7	**-1474**	353	**2180**	353	134	**-2277**	275	**2827**	275	97
Jib Position 8	-939	1645	1645	-939	**134**	-1530	2080	2080	-1530	97

Legend: RA: Reaction at A; RB: Reaction at B; RC: Reaction at C; RD: Reaction at D; HF: Horizontal Force at each leg

14(e) Load Table



14(f) Holding Down Bolts

Figure 14 – Tower Crane Foundation Design

5.7 <u>Crane Erection</u>

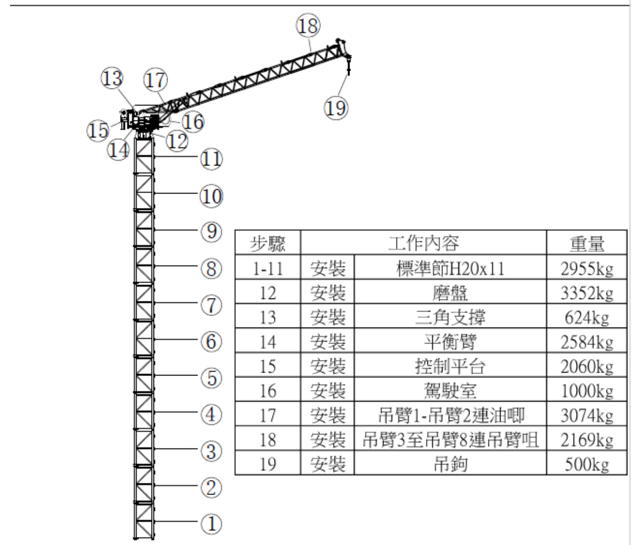
After concreting of the foundation block, and the concrete has gained the design strength, the fixing angles of the tower mast legs of the crane are fastened onto the foundation block using high strength steel bolts (Figure 14(f)).

A method statement for crane erection showing the step-by-step procedures, together with the manufacturer's reference material, should be submitted. The erection sequence, and weight of the various parts of the tower crane to be erected and a layout plan, as those shown in Figure 15, should be included. The following should be marked in the layout plan:

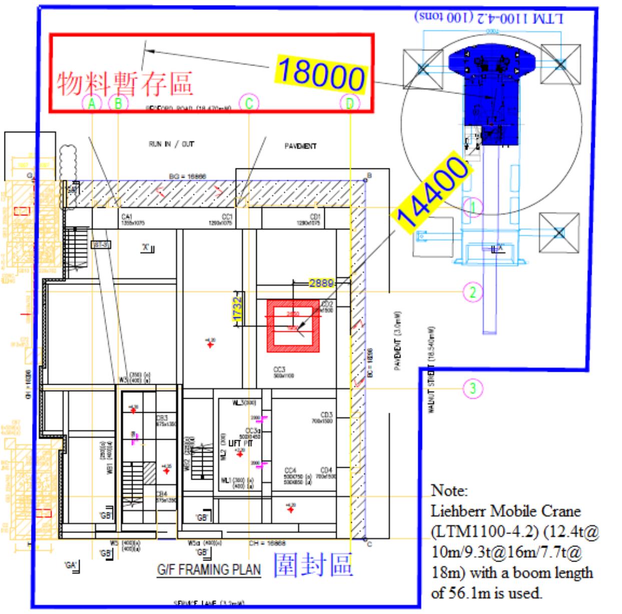
(a) type/name/brand name/model number of the hoisting facilities used for erecting the tower crane;
(b) distance between the hoisting facilities and the centre of tower crane;
(c) distance between storage area for hoisting facilities and centre of the tower crane;
(d) hoisting area of the hoisting facilities;
(e) radius of the hoisting facilities and their maximum safe working load;
(f) exclusion zone for the erection work; and
(g) storage area for parts of the tower crane, jib and counter-jib.

The erection of the tower crane begins with erection of the tower masts Upon reaching the designed height, the slewing ring is erected on top of the tower masts. Other components, in the order of the cabin, jib and counterjib, trolley and hook block, counterweight, etc., are installed.

工程項目: 使用油壓大吊安裝COMEDIL CDK100-16 天秤
起重臂長度:21.5m 標準節高度:41.25m
工程序書



步驟	工作內容		重量
1-11	安裝	標準節H20x11	2955kg
12	安裝	磨盤	3352kg
13	安裝	三角支撐	624kg
14	安裝	平衡臂	2584kg
15	安裝	控制平台	2060kg
16	安裝	駕駛室	1000kg
17	安裝	吊臂1-吊臂2連油唧	3074kg
18	安裝	吊臂3至吊臂8連吊臂咀	2169kg
19	安裝	吊鉤	500kg



(a) (b)

Figure 15 – Erection Sequence of a Tower Crane

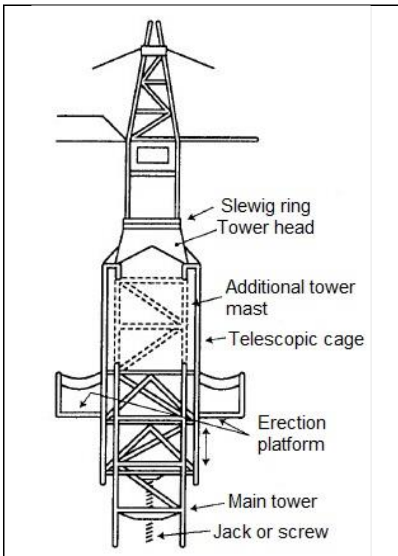
5.8 Crane Height Alteration

The crane height alteration is the most dangerous operation in the lifting operation, and hence special care must be given to this operation.

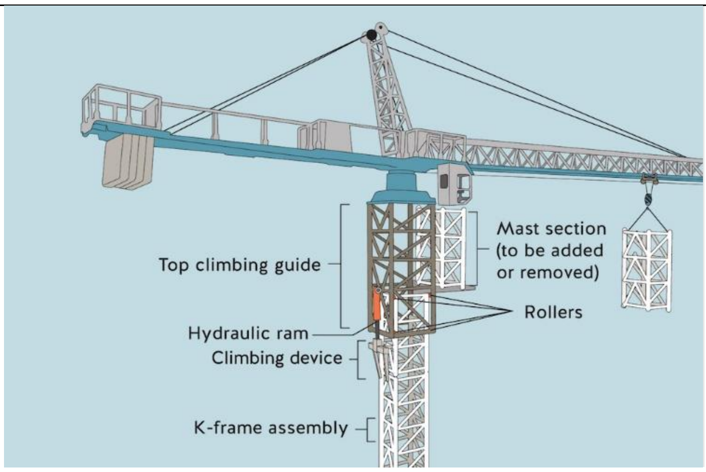
There are two modes of increasing the height of a crane, dependent on the whether the crane is climbing externally or internally, as follows:

(a) External climbing (or top climbing). There are two types of top climbing system: (i) telescopic system and (ii) climbing frame system, as shown in Figure 16. The type commonly used is the climbing frame system.

Details of the telescopic system are given in Section 5.3.1 (see Figure 9(c)).



(a) Telescopic



(b) Climbing Frame

Figure 16 – Types of Top Climbing System

In the climbing frame system, the climbing frame is the key element. It is a square frame with an opening on one side and a hydraulic pump and ram at the bottom (Figure 17(a)). The rams jack the climbing frame up, raising the cabin and jib. A new section of the mast is then hoisted up and slid into place in the open side of the climbing frame (Figure 17(b) and (c)). Once that new section is bolted in, the climbing frame can be jacked again, until the crane has reached the desired height.

The crane must be balanced before the climb to ensure that there is no moment acting on the crane (Figure 17(d)). A specified hook load will be held at a specified radius, and field adjustment of the radius is needed to achieve a fine balance. There should be no torque acting on the crane as well. New mast sections are placed on the ground in a straight line such that slewing of the jib is not needed as the new mast sections are lifted. The slewing switch is locked to ensure that the crane will not slew accidentally.

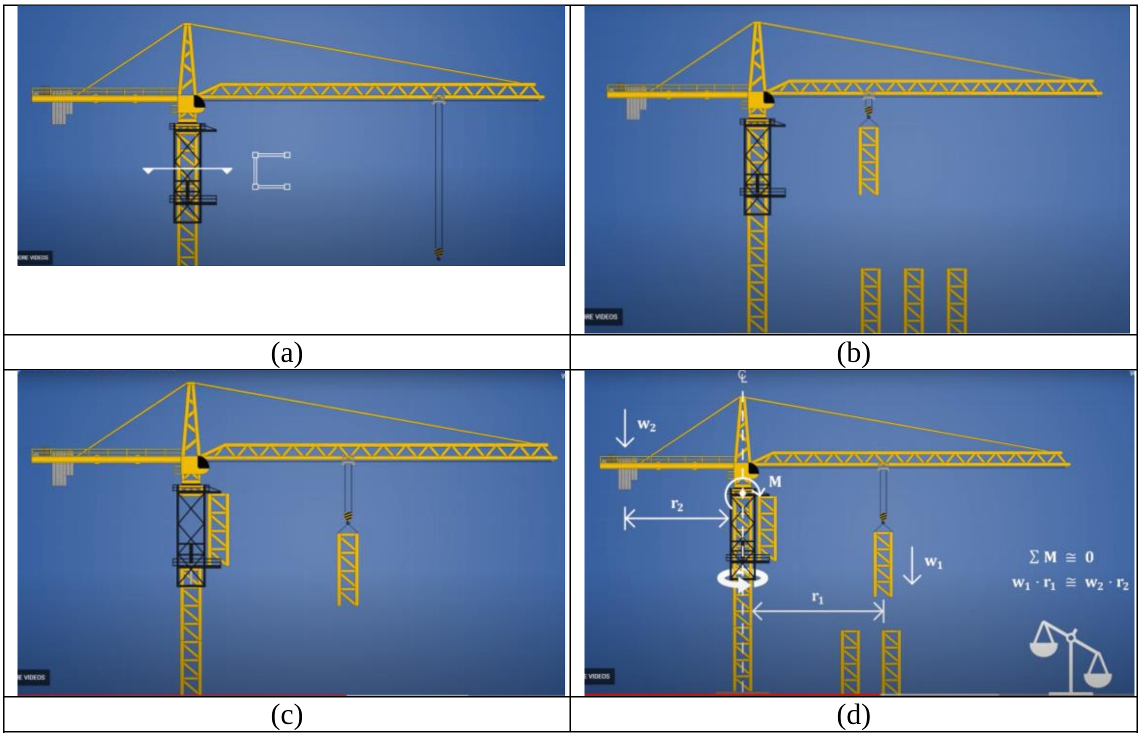
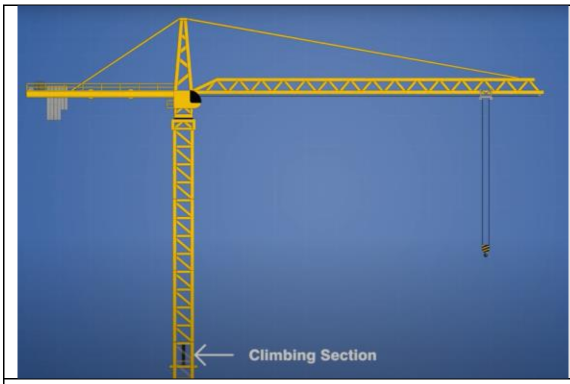


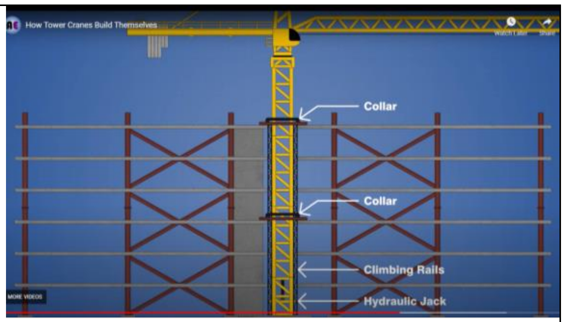
Figure 17 – External/Top Climbing Using Climbing Frame

(b) Internal climbing. In this method, the weight of the crane is carried by the building and a tall mast is not needed. This will increase the lifting capacity of the crane and save cost. This method is mentioned in Section 5.3.3 (See Figure 11(c)). Initially, the crane is securely anchored to the base of the building to act as a fixed crane and used for the construction of the lower parts of the building (Figure 18(a)). Holes are left in the floors round the mast of the crane. When the building reaches three storeys, collars are fitted round the mast at the floor (Figure 18(b)). Flanged wheels are fitted to the collars in which the angle members of the mast run. The tower is then hoisted to a higher level by hydraulic jacks, and wedged in position to the collars which transfer the crane loads to the floors (Figure 18(c)). The bottom collar can be removed and used for the upper floors (Figure 18(d)). The process is repeated until completion.

The floor structure must be designed to take the weight and loads from the crane, which is mounted on steel joists spanning on to main beams. Alternatively, the crane may be mounted in a lift shaft, but this presents difficulties in shuttering when the walls of the shaft are of reinforced concrete.

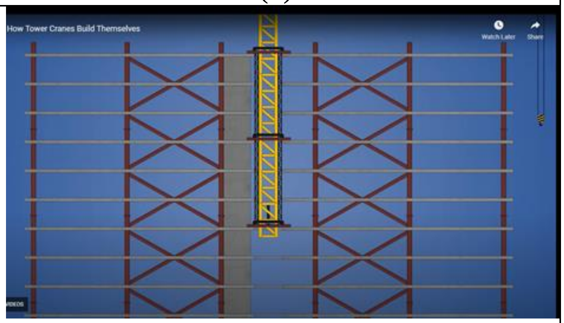


(a)



(b)

(c)

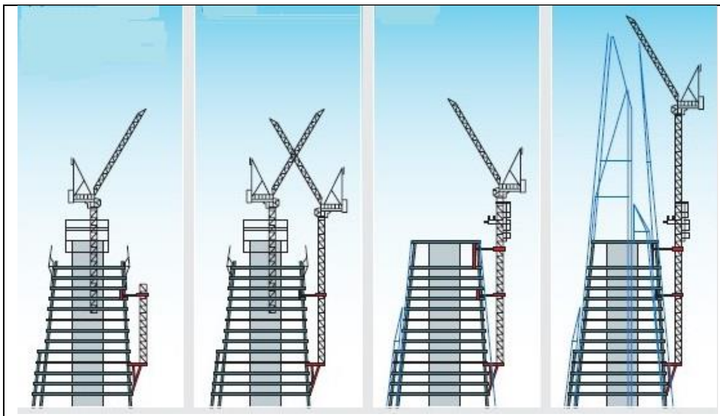


(d)

Figure 18 – Internal Climbing

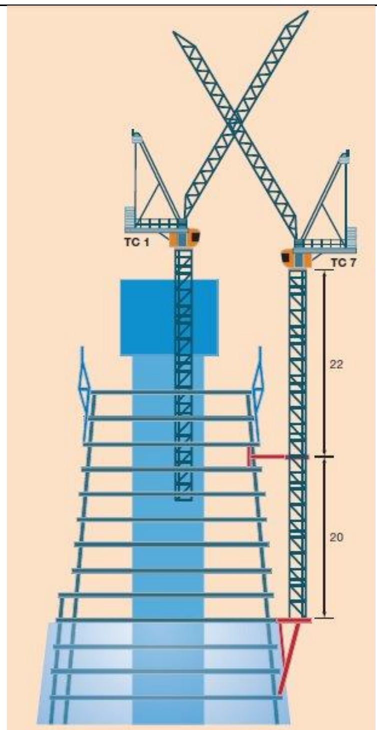
Another way of altering the height of a crane within a building is use of a climb-form. A tower crane can be attached to a climb-form rig, which could rise steadily up the building with the climb-form as the building is constructed. The term climb-form is used to describe both slip or jump forms. The power for the climbing operation is provided usually by hydraulic rams or electric motors connected to climbing feet or screw feet or screw shafts. Slip forms usually climb slowly and continuously during the concrete pour. As the slip form rig is raised, it is supported by the cast concrete walls below. This allows high smooth concrete structures like chimneys to be constructed without obvious joints. Jump forms climb in steps following each concrete pour. This type of construction is more suited to high rise building cores where there are regular levels (floors) and joints will not be seen.

The height of the crane at the centre core of the Shard building project was extended using slip form (Ingenia, 2012) (Figure 19). The crane was designed to hang off of the slip form in the middle of the concrete core that built the exterior walls of the core from basement 3 to level 72[17]. There was no base to the tower crane and the crane was carried upward with the core.



(i) The main structure was constructed using tower crane slipforming up the central core.
(ii) The central core crane was used to build second crane that cantilevered off the building from level 55.
(iii) The cantilevered crane was then used to help dismantle the central core crane.
(iv) The cantilevered crane was used to construct the 66 m tall steel spire. The cantilevered crane jumped even higher as the spire grew.

(a)



(b)

Figure 19 – Slipforming for Tower Crane

5.9 <u>Crane Dismantling</u>

The steps taken in crane dismantling are the same as those in the erection given in Section 5.7, except that the steps are performed in the reverse order. Crane dismantling, however, in many instances is more difficult and potentially dangerous than erection because of the heights involved and the interference of the structure that the crane is used to build. Other conditions that change during the time of the crane's use also affect the dismantling procedure, for example, corrosion of pins and bolts. The requirements for dismantling and removing the crane must be considered at the outset of the project when selecting the type, size and location of the crane.

A method statement for crane dismantling should be submitted. The dismantling sequence, and weight and length of the various parts of the tower crane to be dismantled, as shown in Figure 20, and a layout plan should be included. The following should be marked in the layout plan:

(a) distance between the hydraulic derrick crane and the centre of tower crane;
(b) name/brand name/model number of hoisting facilities for dismantling a tower crane;
(c) distance between storage area for hoisting facilities and centre of the tower crane;
(d) hoisting area of the hoisting facilities;
(e) radius of the hoisting facilities and their maximum SWL;
(f) exclusion zone for the dismantling work;
(g) storage area for parts of the tower crane, jib and counter-jib; and

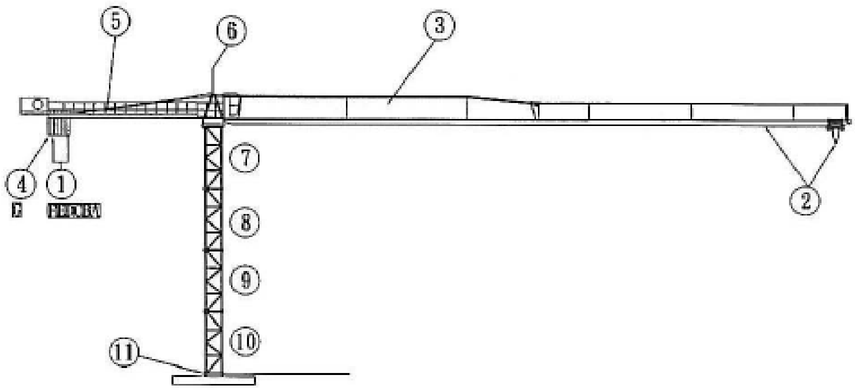
[17] https://www.cranestodaymagazine.com/features/from-a-london-landmark-to-a-world-of-lift-planning-4198507//image/from-a-london-landmark-to-a-world-of-lift-planning-4198507-451772.html

(h) the condition of the ground for supporting the derrick crane, way and materials for cushioning, weight to be carried by ballast of hydraulic derrick crane (if a hydraulic derrick crane is used).

A sample method statement for dismantling of a tower crane is given in the Guideline on Safety of Tower Cranes (CIC, 2010).

Site Name : ______________________

Project Item : ______________________



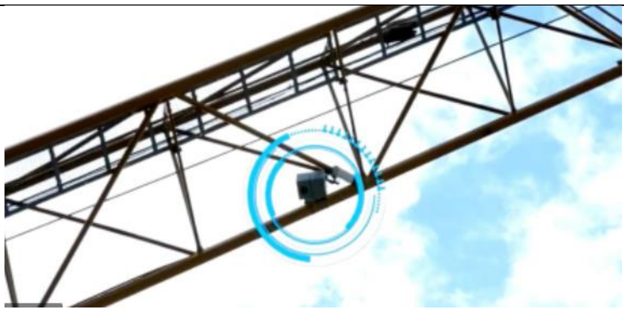
Dismantling sequence and weight and length of various parts

Dismantling steps	Name of parts	Weight	Length
1A	counter-jib ballast	2.1 tonnes	1940 mm
1B	counter-jib ballast	2.1 tonnes	1940 mm
1C	counter-jib ballast	3.15 tonnes	2840 mm
1D	counter-jib ballast	3.15 tonnes	2840 mm
1E	counter-jib ballast	3.15 tonnes	2840 mm
1F	counter-jib ballast	3.15 tonnes	2840 mm
2	hook	0.53 tonnes	1710 mm
3	jib + trolley	9.3 tonnes	60000 mm
4G	counter-jib block	3.15 tonnes	2130 mm
5	counter jib + hoisting drum	9.2 tonnes	15840 mm
6	A-frame + slewing ring + cabin	7.3 tonnes	4720 mm
7	mast	1.86 tonnes	6000 mm
8	mast	1.86 tonnes	6000 mm
9	mast	1.86 tonnes	6000 mm
10	mast	1.86 tonnes	6000 mm
11	concrete footing		

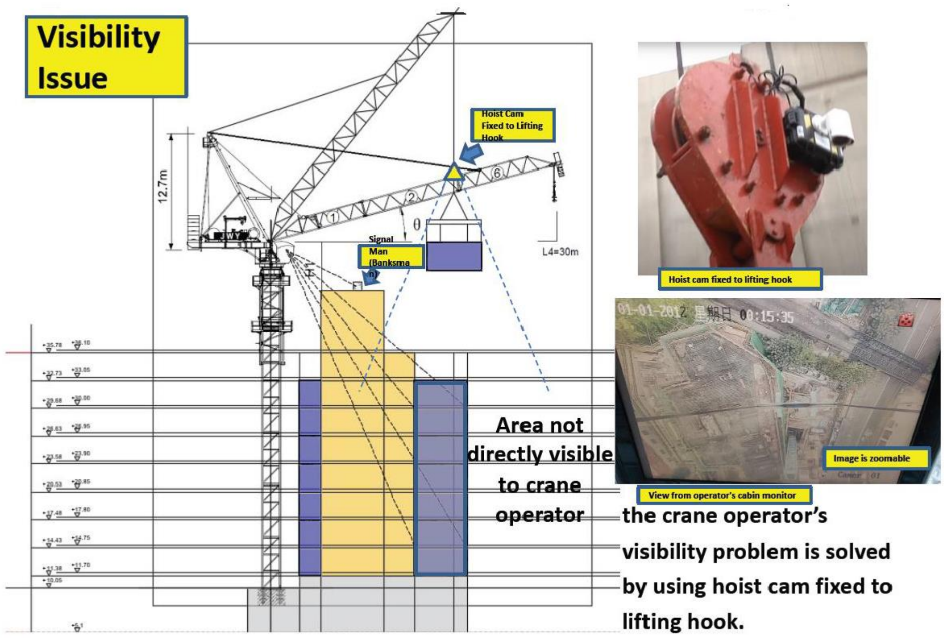
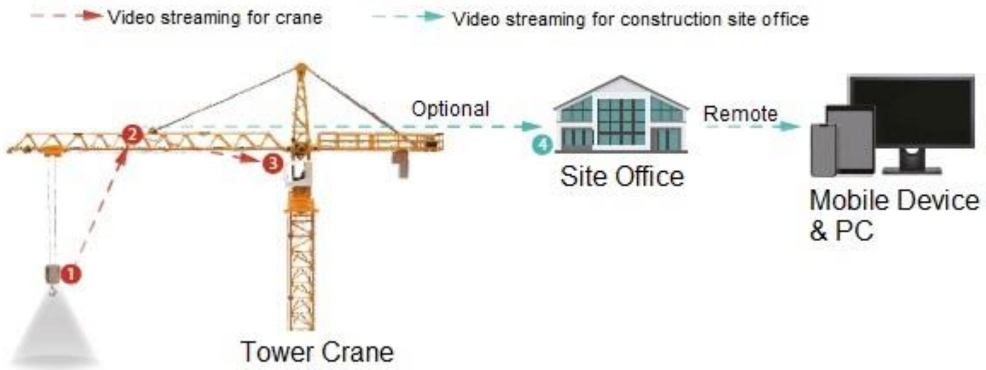
Figure 20 – Dismantling Sequence of a Tower Crane (after CIC (2010))

5.10 Technologies Facilitating Crane Safety Operation

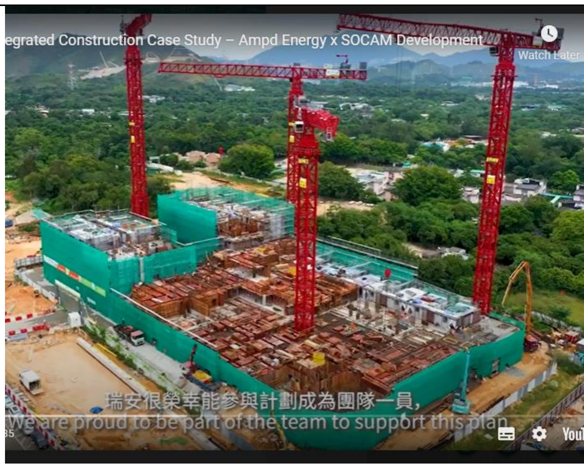
Safety is of primary concern in the lifting operation. The following technologies facilitating crane safety operation, as shown in Figure 21, should be considered.

Safety Operation Measures	Description
Use of High-resolution Camera and AI Solutions	Two high-resolution camera systems are available: Anavision[18] and Versatile[19]. In the Anavision's system, a high-resolution camera is mounted on the jib to take pictures for the entire duration of the construction project. Through AI image analysis and 3D reconstruction, a high-resolution floor plan can be produced. By overlaying the drawings produced using a BIM model for comparison, the tower crane camera solution is able to detect construction errors, such as external wall errors before building the next new floor, and allow on-site corrections in advance to avoid high rework costs in the future, thereby greatly improving the working efficiency of site surveyors and reducing the manpower. The camera can be used as a long-time aerial standby to take high-density measurement of a large area within the construction site. It also greatly reduces the number of workers to work in the danger area, and improves the safety of the working environment on the site. Inspection report can be sent via email, which helps speed up follow-up actions and decision-making. In the Versatile's CraneView system, an IoT sensor device is mounted to the crane hook, which is used to collect and analyzes data on the flow and handling of materials, production rates, and crane utilization. A camera affixed to the device records all crane activity allowing a view of the live feed or a lift sequence from any point in the schedule. Using AI, the device learns and classifies each item picked, captures the weight of the item, and records the cycle time of the lift so the team can understand exactly how the crane is being used. Through an online and mobile dashboard, project teams review data, set custom alerts and notifications, and view weekly reports generated.
	 

[18] https://anavision.com/blog/tower-crane-camera-solution/
[19] https://www.versatile.ai/craneview-solutions/

<table>
<tr><td rowspan="2"></td><td colspan="2">The high-resolution camera mounted on the hook can provide the crane operator a wider view of the hoisting conditions, in particular in area where his view is obstructed (see footnote 8), and allows him/her and the control centre to make instant response as appropriate.</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Hercules Wireless Crane Camera System[20]

</td></tr>
<tr><td>1 HOOK BLOCK
Wireless Hook Cam
 Easily deployed to the hook block for real-time load view
 2K QHD, 3MP ultra-wide audio-visual feeds
 128GB SD card recording capacity
 Starlight & defog enhancements for clear, full color video in low-light
Solar Panel Battery Pack
 Sustainable for more than 35 hrs of camera work time
 Battery level indicated on the monitor
 Power Saving for up to 4 days of operation (working 8 hours daily)
 Fast & simple to install, remove and charge
Hook AP
 Transmit real-time camera footage to StreamLink Station
 WiFi 5G technology</td><td></td></tr>
</table>

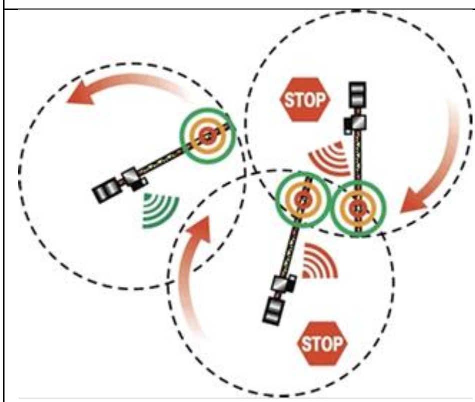
[20] https://www.topinst.com/

	2 JIB **Ultra-Long StreamLink Station** - Extended communication range with ability to bypass obstacles & with Industrial-leading WiFi 5G ultra-long StreamLink technology - Real-time, stable video via 802.11 a/c high-speed transmission	
	3 CABIN **Touch Monitor** - Operator live views of load and critical surroundings - Streaming up to 4 channels audio-visual feed simultaneously - Administrator Account giving support to cameras control & playback - Scaleable to maximum 3 Android tablets (optional) **Cabin AP** - Connected to StreamLink via Wi-Fi 5GHz high-speed technology - Projected 2K live audio-visual feed to the Monitor via Wi-Fi 2.4GHz	
	4 **SITE OFFICE** **Scarlet Network Video Recorder** - Monitoring worksite anytime, anywhere - Streaming up to 9-channels at the same time - 1TB HDD video storage (upgrade for 8TB)	
AMPD Enertainer[21]	The Enertainer is an advanced energy storage system. It runs on Li-lon batteries simiar to those used in electric vehicles. It can be charged up to 80A 3-phase but usually a current of 10A to 40A will suffice. The Enertainer's input voltage range is 320-440 VAC (3-phase), and the output voltage range is 380-415VAC (3-phase+neutral). The Enertainer has internet connectivity that enables remote monitoring, device management, remote troubleshooting and data analytics. Four Enertainers were used to power four 64 ton tower cranes for a MiC project at Kwu Tung, reducing CO_2 by 61% and saving HKD854,000/yr on diesel fuel cost.	
		

[21] https://www.ampd.energy/

<table>
<tr><td>Crane cabin[22]</td><td>Most cranes are now built in with a crane cabin with improved ergonomics, size, visibility and comfort. Wide glass panels, protected by side bars are provided which ensure excellent visibility. Multifunction joysticks, touch screen with color display, etc., are provided to simplify crane control and monitoring. The adjustable slewing seat and built-in heating and air conditioning system keep operators comfortable, productive and focused on their work to maintain safety.</td></tr>
<tr><td></td><td> 
</td></tr>
<tr><td>Anti-collision System[23]</td><td>Tower cranes are normally built and operate near residential area. When more than one cranes, such as tower cranes, derrick cranes, etc., are used, an anti-collision system (ACS) should be used. The ACS is capable of tracking and monitoring accurately the locations of the cranes operating within the overlapping zone, including jib, trolley and hook movements.

The ACS consists of an emitter, a sensor module and a reflector. Infrared waves are emitted from the emitter in the direction of the reflector. The reflector reflects the infrared waves back to the sensor. When two tower cranes are close, the reflected infrared waves will be detected by the sensor, which will intervene automatically the crane mechanisms to slow down the speed of the crane or stop the crane movement to prevent collision. A continuous audible and visual signal at the operator’s cabin will be produced to remind the operator to slow down the crane movement when approaching a zone with a risk of collision.

The distance between the reflector and the sensor to detect the infrared waves can be adjusted using the potentiometer provided in the system. The maximum distances between the two cranes to generate an alarm signal is about 10 m.</td></tr>
<tr><td></td><td>
</td></tr>
</table>

[22] https://www.liebherr.com/en/chn/products/construction-machines/tower-cranes/licab-crane-cabin/licab-crane-cabin.html
[23] Ser (2021).

Independent Safety Audit [24]	Arranging an independent safety audit of the lifting operation is a pro-active way to monitor the safety performance of the lifting operation, promote safety management concept and improve the safety standards. The independent site audit should be carried out by a safety auditor accredited by the Occupational Safety and Health Council (OSHC) as an Accredited Safety Auditor (ASA). The independent safety audit should be conducted once every three months during the whole lifting operation stage. At the independent safety audit, (a) information on the efficiency, effectiveness and reliability of a safety management system in respect of the operation will be collected, assessed and verified, and (b) improvements to the system will be considered. The Principal Contractor is responsible for liaising with the ASA on the carrying out of the safety audits and shall provide all facilities, access and assistance to the safety auditor. In this regard, the Project Manager or his delegate and the Responsible Person shall be responsible for the proper execution of the safety audits and attends the site audit and 'open' and 'close-off' meetings of every safety audit. The RSO shall attend all safety audits. The independent safety audit report is submitted to the project client for review. Suitable clauses should be included in the contract for the provision of the independent safety audit for the lifting operation.
F&IU Safety Audit	Under the Factories and Industrial Undertakings (Safety Management) Regulations (F&IU(SM))R, the contractors are required to establish and implement a safety management system (SMS) to manage safety and health when they (i) engage 50 or more workers in construction sites; or (ii) are running construction work contracts worth $100 million or more. The SMS is subject to regular assessment by safety audits or safety reviews. In addition to developing and maintaining a SMS in accordance with the F&IU(SM)R, the contractors must appoint a Registered Safety Auditor (RSA) to conduct safety audits once every six months. The audit reports with recommendation plans are submitted to the Labour Department for review.
Internal Safety Audit	An internal safety audit for the lifting operation should be arranged. The internal audit should be a planned audit according to a written procedure in the safety plan and conducted by the RSO or project manager who is participating in the job. The focus of the audit will be put on the physical conditions rather than the safety management system, in particular, the assessment of the effectiveness and thoroughness of inspection.
Safety Briefing and Lifting Zone	Before carrying out the work, a safety briefing should be conducted to ensure that the personnel involved understand their roles and responsibilities, and the correct procedures/sequence of tasks. A lifting zone of sufficient size to contain any possible structural failure of the crane with appropriate warning sign displayed should be established while the work is being carried out. The areas should be fenced off and persons not involved in the work should be prevented from entering or working in the area of operation. Walkie-talkies with specific channel should be provided to tower crane operator and signaler for clear communication.

[24] HKHA (2007).

Lifting Gear/ Equipment[13]

Lifting frame and double safety latch should be used. The angle between 2 slings should be limited to less than 90°. The maximum age that the cranes can operate on-site should be specified.

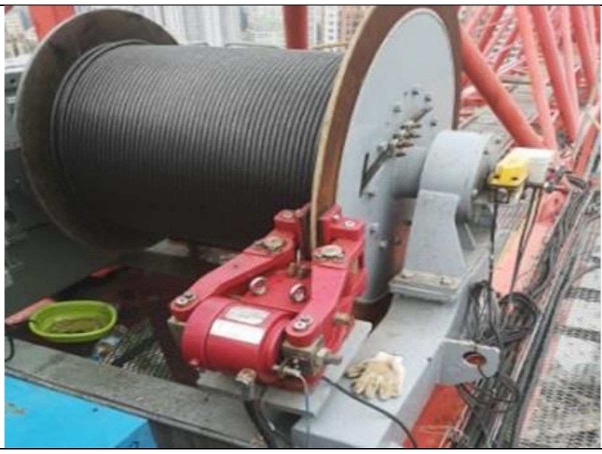
A maintenance manual of the lifting appliances and lifting gear used should be prepared.

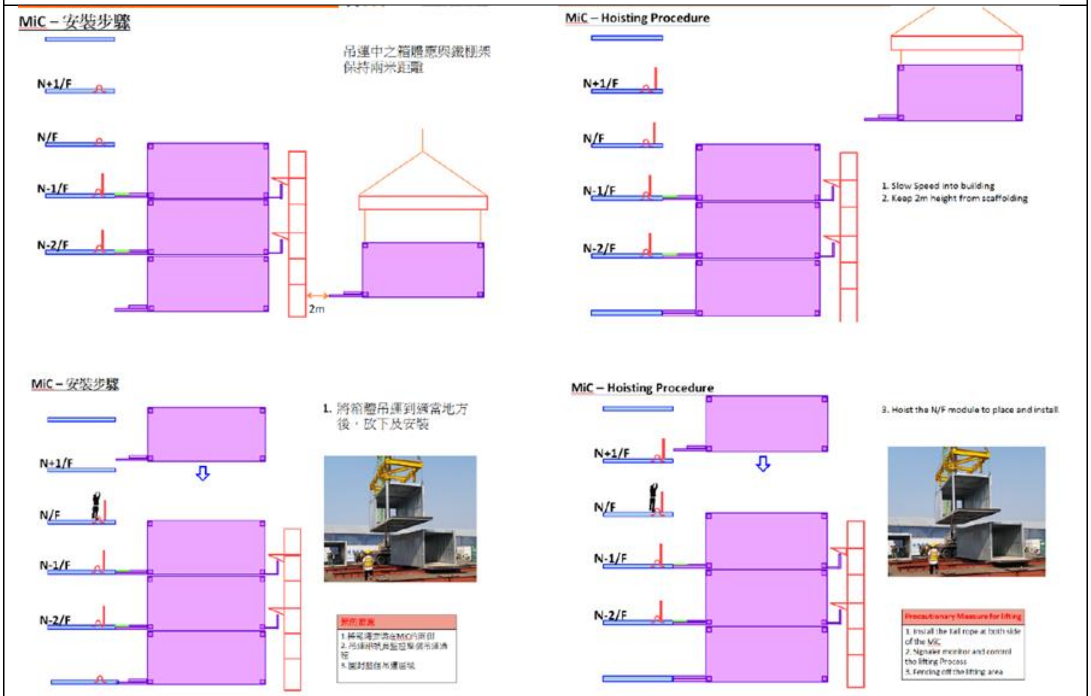
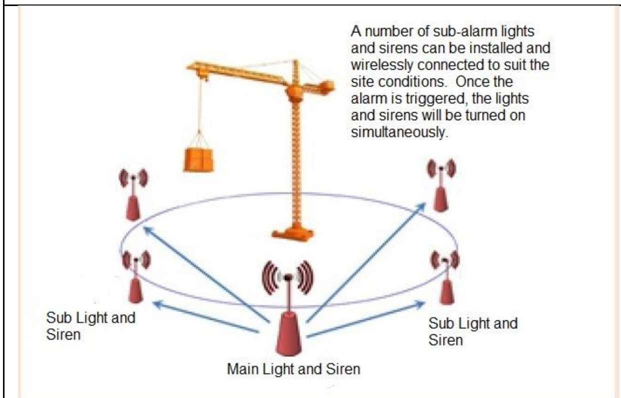
Major construction plant	Overhaul ages (years) 1st Overhaul	2nd Overhaul	3rd Overhaul	Maximum ages of crane on site (years)
1. Tower cranes (rented)	10	17	22	25
2. Tower cranes (self-owned)	14	23	30	35
3. Derrick cranes (used for installing and dismantling tower cranes)	10	17	22	25
4. Mobile cranes (excluding crawler cranes)	12	20	26	30
5. Truck-mounted cranes	12	20	26	30
6. Crawler cranes (rented)	15	25	30	35
7. Crawler cranes (self-owned)	20	30	35	40

Second Brakes[13]

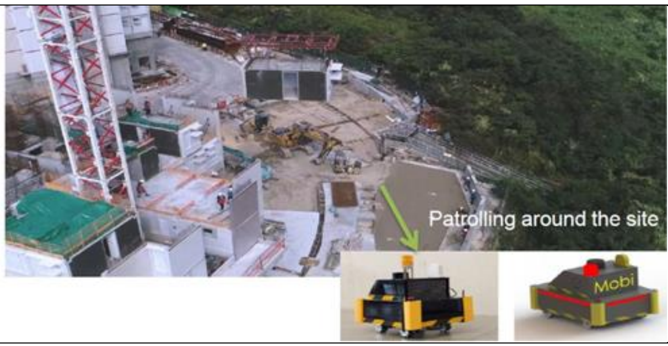
Tower cranes are provided with fail-safe brakes in that brakes will be applied automatically when there is a loss of power. These brakes will not be released unless the power has been restored or they are released deliberately. For the brake on the hoisting drum, no belts or chains should be provided between the brake and the drum. The brake on the slewing drive must be capable of preventing the jib from drifting up to the maximum operating wind pressure specified by the manufacturer.

A second brake has been specified by HD since 2017 (Ser, 2021) to handle situations not covered by the primary brake and offer further protection when the primary brake fails.



Method Statement for Lifting[25]	An annotated method statement in Chinese/ English should be prepared to aid understanding of the lifting methods. The method statement should cover, among others: (i) the measures for avoiding or mitigating the hazards identified in the risk assessment; (ii) step-by-step procedures supplemented by diagrammatic illustrations; (iii) highlighting of critical hazards and safety precautions by words such as "Danger", "Caution" and "Hold Points"; (iv) procedure and instruction on dealing with "Hold Points" of critical parts; etc.  The step-by-step procedures shown on the plans approved by BD should be referred to.
Use of Technology to alert Workers of Descending Hook[13] [26]	A number of lights and sirens are installed in the proximity of the crane with radio frequency identification (RFID) tags attached. A continuous audible sound and light will be produced to alert workers when the hook is lowered to a designated height.  

[25] Mok (2021).
[26] Hoist Plants & Machineries Co. Ltd.

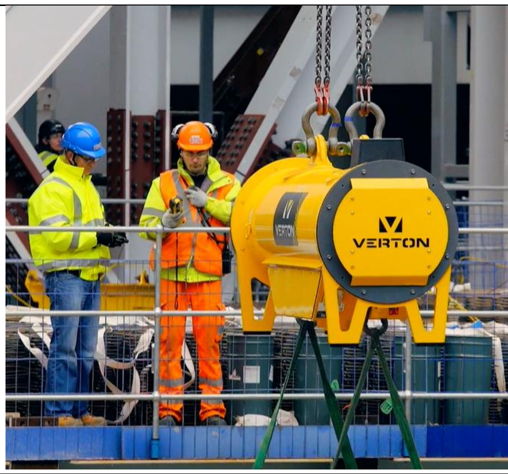
Use of Smart Devices in Safety Control[27]	In the Housing Society's Hung Shui Kiu Phase 1A project, a MobiSafety Robot, making use of 5G and ultra wide band (UWB) technology, was used to patrol around the site to provide virtual fencing and security alerts for lifting and installation clearance for the MiC modules.
	
Crane control system[28] [29]	A highly computerized crane control system is now provided for most tower cranes, e.g. Litronic Crane Control System in Liebherr cranes and Manitowoc Crane Control System/ Potain MDT Crane Control System in Potain cranes. These systems provide an one-level interface between the crane and driver. Various analysis tools are built in to provide information on the operation. These systems empower the driver to efficiently control the crane and optimize turnover. The following fields of action are provided: motor and hydraulic management, safety and diagnosis systems, communication and information systems and machine data recording.
	 
High tensile strength fibre rope[30]	High tensile strength fibre rope is provided in some cranes, e.g. in Liebherr cranes. This type of rope is light and helps to increase lifting capacity. The reduction to one-fifth of the weight increases the crane's capacity by 8% over the entire moment range and a maximum capacity of up to 20%.
	

[27] Cheung (2021).
[28] https://www.liebherr.com/en/chn/products/construction-machines/tower-cranes/tower-crane-litronic/tower-crane-litronic.html
[29] https://www.manitowoc.com/sites/default/files/media/divers/file/2020-06/02BR_MDTCCS_032018_EN.pdf
[30] https://www.liebherr.com/en/chn/products/high-strength-fibre-rope-solite/fibre-rope_old.html

Crane driver elevator[31]	This elevator is designed to transport two people or a payload of 200 kg. This allows the crane driver or maintenance personnel to get to his workplace quickly. Access ladders are installed in parallel to the operator lift. Access gates on departure and arrival are provided.  
Micromove fine positioning mode	A micromove fine positioning mode is built-in in some cranes, e.g. Liebherr cranes. This function allows loads to be positioned particularly gently and with millimetre precision using a speed reduced to ¼ of the normal speed. This function is particularly good for lifting and installation of MiC modules. The micromove fine positioning mode comes with two advantages: (i) the workpieces can be placed down with the utmost care and precision at micro-speed and full control lever distance; and (ii) components can be kept suspended without the brake taking effect. This guarantees a smooth and gentle restart. The micromove function can be activated directly at the control lever. 

[31] https://www.liebherr.com/en/chn/products/construction-machines/tower-cranes/top-slewing-cranes/crane-driver-elevator-liup/crane-driver-elevator-liup.html

<table>
<tr><td rowspan="2">Automated lifting device (ROBORIGGER, VERTON)</td><td colspan="2">It is an automated lifting device which can accurately rotate and hold loads in a specific orientation regardless of wind. No taglines are needed. It is a game changer for lifting safety as personnel no longer need to be in a position where they can be injured by lifted loads. The device can increase productivity of crane operations by 10-30% and greatly extends the operating window for lifting loads with large windage. It also allows loads to be easily manoeuvred into tight locations without the need for the required personnel to guide the load. It eliminates the risk of damage to the load or the surrounding structure. The device is ideal for use on construction tower cranes and mobile cranes.

https://www.roborigger.com.au/products/roborigger-load-orientation-system/
https://www.verton.com.au/everest-series</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="3">Figure 21 – Technologies Facilitating Crane Safety Operation</td></tr>
</table>

6. MOBILE CRANES

6.1 General

In the sections that follow, a description of the mobile crane key components and crane type is given, followed by a discussion of the considerations for mobile crane selection. Details of the mobile crane erection and dismantling procedures are given in the CoP for Safe Use of Mobile Cranes (LD, 2017b), and are not covered here.

6.2 Crane Key Components and Sensors

The key components of a mobile crane is shown in Figure 22. A mobile crane consists of a jib, counterweight, cabin, load hook, and outriggers, etc.

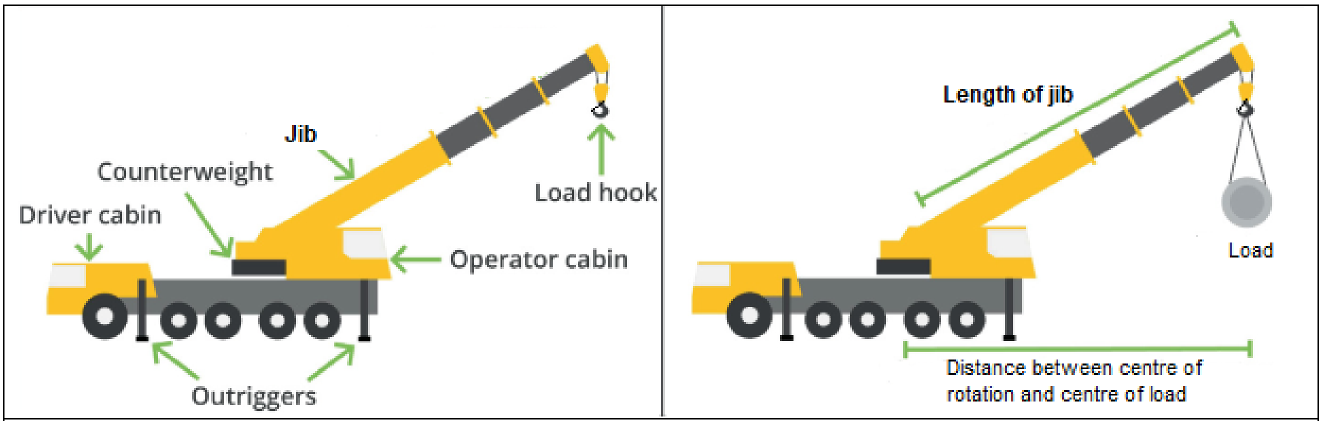


Figure 22 – Key Components of a Mobile Crane

To ensure safe operation of mobile cranes, the following safety features are provided, as shown in Figure 23:

(a) Automatic safe load indicator[2]. This device indicates if the load lifted by a crane is within the safety range or not. It will alert the operator when the load is approaching the crane's SWL and the maximum weight is exceeded. The automatic safe load indicator is usually used in association with the overloading cut-out.

(b) Anti two blocks (ATB) system (with hammer). The ATB system helps to prevent the crane's lower load block to come in contact with the jib tip. This could cause damage to the hoist line (winch rope) because it induces a lot of impact force during collision. The two-block can cause injury or death, as well as damage to the crane, hoist line and ball hock or hook block.

(c) Jib angle indicator. The indicator is capable of moving in the vertical plane. The indicator should be clearly visible and readable by the operator at his control cabin to the nearest degree.

(d) Hydraulic pressure/load cell. This device is fitted to check the load acting on the hydraulic jack.

(e) Outriggers. The outriggers are used to keep the crane stable during lifting. The "H style" system is often used, which consists (i) two to four stabilization legs; (ii) center tube;

(iii) pump and manifold assembly; (iv) control panel; and (v) wiring harnesses, hoses, and connectors. The legs are proportionately sized to provide the necessary support for each particular crane's design and lifting capacity. It is important that the operators read and fully understand the manufacturer's instructions and know exactly how to extend the outriggers on their particular crane. It is critical that lifting should commence only after the outriggers are extended and in proper position. A sensing system is built in in some cranes to prevent crane operation if the outriggers are not fully extended, or to prevent crane moving if outriggers are not properly stowed. Outrigger pads/mats/timber blocks should be used under the support plate for stabilization. Outrigger pads/mats/timber blocks are available from a variety of suppliers in different materials and sizes.

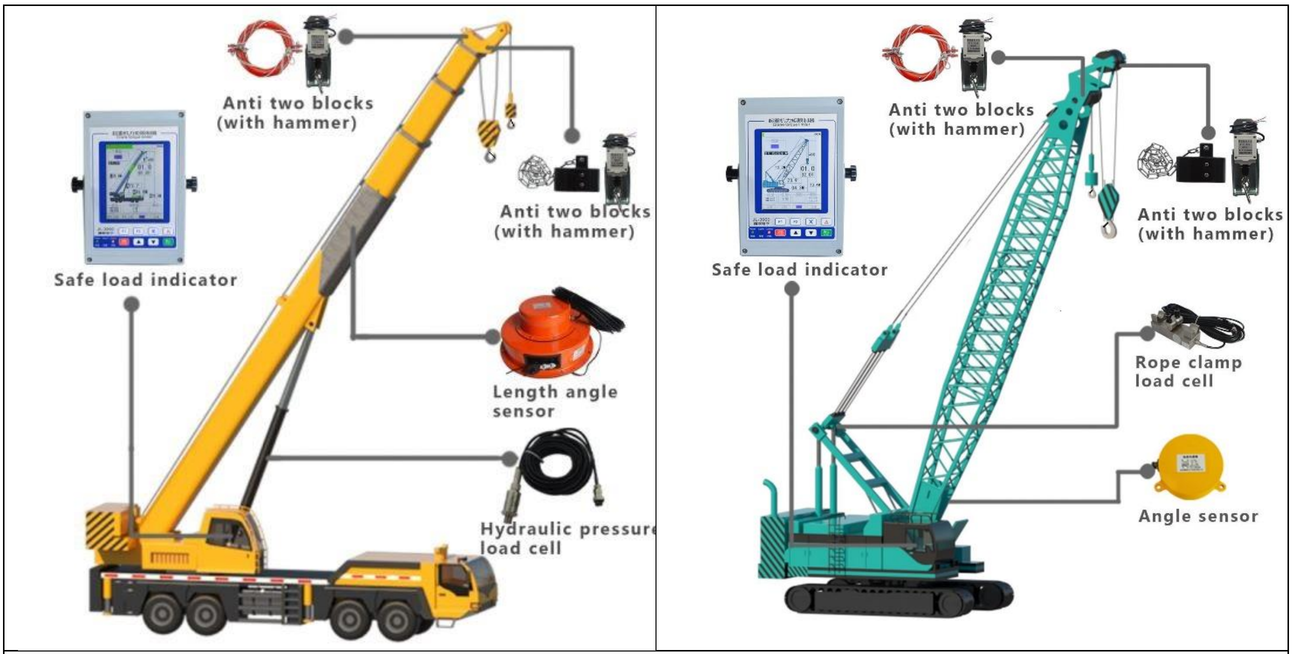


Figure 23 – Sensors Installed in Mobile Crane

6.3 <u>Crane Type</u>

6.3.1 <u>Mounting Configuration</u>

In terms of mounting configuration, mobile cranes are available with crawler-mounted, truck-mounted and wheel-mounted, as shown in Figure 24.

Use of crawler-mounted crane should be considered in ground conditions which is poor to travel over or sloped, in areas of limited access or in projects in which handling of dynamic loads, such a vibrators, is involved. In general, crawler-mounted or wheel-mounted crane is used in most local lifting operations. While those involving considerable travelling between sites during lifting operations, truck-mounted crane is used.

(a) Crawler-mounted Crane

(b) Truck-mounted Crane

(c) Another Mode of Truck-mounted Crane

(d) Wheel-mounted Crane

Figure 24 – Type of Mobile Cranes in Terms of Mounting Configuration

6.3.2 Jib Configuration

In terms of jib configuration, the three types available are telescoping jib, strut-type jib and fly-jib, as shown in Figure 25.

In telescopic jib, jib length can vary. This allows easy maneuvering and placing loads in confined areas. The operational set-up and strip-down time of this kind of jib is shorter than the other types. However, the working loads at longer radii are less than those at comparable radii of a lattice strut-type jib and the maximum length of the jib is restricted to the jib's relative heavier weight.

The strut-type jib provides greater heights of lift and maximum operating radii, and hence is more suitable for long range of work or high lifts. However, a bigger set-up area of the lattice strut-type jib is required in the jobsite as compared with the telescopic jib.

The fly-jib is suitable for operations involving handling of relatively light loads to extremes of height.

(a) Telescopic Jib

(b) Strut-type Jib

(c) Fly-jib

Figure 25 – Type of Mobile Cranes in Terms of Jib Configuration

6.4 Crane Selection

If it is decided that a mobile crane is used for the MiC project, then the following factors should be considered in the selection of the type of crane and jib for the project:

(a) Weight of modules. The weight of modules are shown on the plans approved by BD but subject to confirmation by RSE/RC/prefabrication factory. It is important to select a crane with a suitable lifting capacity to move the modules. It is a waste of time, labour and money if a crane with a capacity higher than that required is used. On the other hand, use of a low-capacity crane can lead to fatal accidents and cause damage to the modules. However, there are other factors that may affect a crane's capacity, which are beyond what is stated on the load charts, such as outrigger setup, ground conditions, counterweight configuration, wind and impact loading and the need for rapid swinging.

(b) Lift height. The length of the crane's jib needed will depend on how high the modules will be installed. It is necessary to check the weather conditions, particularly the wind. The higher the lift height, the more likely that wind will sway the modules upon lifting, and this may lead to potential accidents.

(c) Moving distance. Within the site, the crane will need to travel some horizontal distance to pick up the modules. If the crane is needed to move the modules from one spot to the other, then a wheel-mounted mobile crane is preferred. The three primary factors, including the counterweight, support structure, and stability of the jib, will play a critical role in traveling this distance safely. The rated capacity[32] of the crane should be checked.

(d) Site conditions, including ground conditions for crane standing, and space available for crane access, erection, operation and dismantling. Use of crane depends on the type of terrain. For rough terrain, crawler-mounted cranes should be used. For flat and firm terrains, truck-mounted crane is a better option. Considerations should also be given to the obstacles likely to be encountered: overhead power cables, streetlight poles, overhead catwalks and scaffolds, buildings, tall trees, etc. These are potential hazards that could affect the operation.

The crane selected should be capable of making the lifts in its standard configuration. There should be at least a 5% working/safety margin with respect to the load capacity on every lift. There should be sufficient clearance for the jib, and adequate headroom between the load and the rigging required to make the lift. There must be enough room in site for full extension of outriggers.

6.5 Siting of Crane

In siting a mobile crane, the following two factors should be considered:

(a) Crane standing or support conditions. Mobile cranes should only be operated on uniform, level and firm ground with sufficient load bearing capacity to withstand the maximum in-service loadings of the crane. Wind loadings and dynamic effect should be taken into account. Reference should be made to the CoP on Wind Effects in Hong Kong 2019 (BD, 2019) for the wind effects and the manufacturer's data relating to the dead weight of the mobile crane and dynamic forces, like those for tower cranes.

Steel plates of adequate strength, suitable mats or suitable timber blocking should be used to distribute the load evenly to avoid collapse of the supporting surface and overturning or collapse of the crane. The mat or timber blocking should be at least 3 times larger in area than the float. When operating close to the edge of a soil slope or an unsupported soil excavation, a safety distance of at least 4 times the width of the foundation (the mat or timber blocking of the outrigger or the crawler) should be maintained between the foundation and the edge, as shown in Figure 26. The distance between the foundation and the toe of the slope or excavation should be at least 2 times the depth of the slope or excavation.

(b) Proximity hazards. Consideration should be given to the proximity hazards in the siting of mobile crane, such as overhead electricity lines and conductors, power cables, radio frequency wave transmitting tower, nearby structure and building, etc. Mobile crane should be sited to avoid loads being handled over occupied premises, highways, etc. The danger to or from underground services, such as gas mains or electrical cables, should not be overlooked.

[32] This is the load that the crane is designed to lift for a given operating condition (e.g. configuration, position of the load). For mobile cranes, the mass (weight) of the hook block is part of the load.

Where there are more than one crane operating, all the crane operations should be coordinated and supervised by a competent person. All the personnel involved including operators, slinger and signalers should be fully informed of the lifting arrangements.

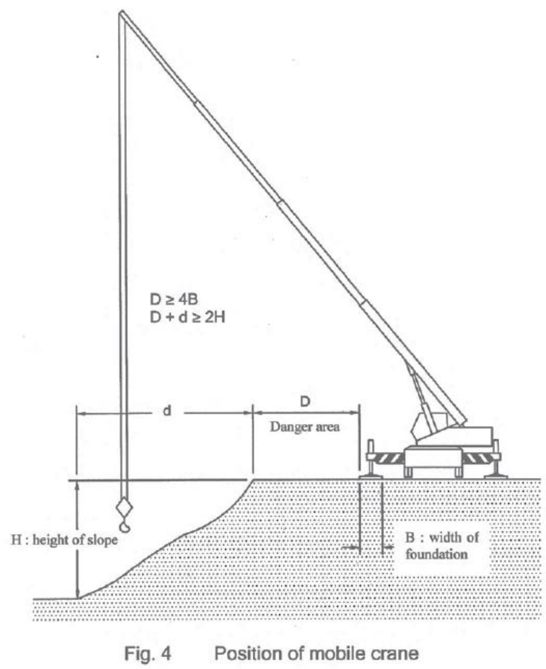


Figure 26 – Position of Mobile Crane Near a Slope (after LD (2017b))

BIBLIOGRAPHY

Abdel-Khalek, H., Shawki, K. & & Adel, Mo. (2013). A Computer-based Model for Optimizing the Location of Single Tower Crane in Construction Sites. Int. Journal of Engineering Science & Innovation Technology, Vol. 2, Issue 2.
http://www.ijesit.com/Volume%202/Issue%202/IJESIT201302_68.pdf

Adrian, A.M., Utamima, A., Wang, K.-J. (2014). A Comparative Study of GA, PSO and ACO for Solving Construction Site Layout Optimization. KSCE J. Civ. Eng. 2014, 19, 520–527.

BD (2009). Technical Memorandum for Supervision Plans 2009.
https://www.bd.gov.hk/doc/en/resources/codes-and-references/code-and-design-manuals/TMSS2009_e.pdf

BD (2019). Code of Practice on Wind Effects in Hong Kong 2019.
https://www.bd.gov.hk/doc/en/resources/codes-and-references/code-and-design-manuals/WindEffects2019e.pdf

BD (2021). Code of Practice for Site Supervision 2009 (2021 Edition).
https://www.bd.gov.hk/doc/en/resources/codes-and-references/code-and-design-manuals/SS2009_e.pdf

BS (1990). BSI - BS 7262. Specification for Automatic Safe Load Indicators,

Cheung, F. K.W. (2021). Hong Kong Housing Society MiC Projects, MiC Workshop on Lifting, Logistics and Transport of Modules, CIC.

CIC (2010). Guidelines on Safety of Tower Cranes.
https://www.cic.hk/files/page/50/Guidelines%20on%20Safety%20of%20Tower%20Cranes%20%28Version%202%29%20July%202010%20-%20e.pdf

CIC (2020). Lifting Safety Handbook.
https://www.safetyweek.hk/web/ebook2020/CIC-LiftingSafetyHandbook-2020.pdf?v=2

CIC (2022). Reference Material on Safety Roles and Responsibilities of Key Stakeholders in the Hong Kong Construction Industry (January 2022).
https://www.cic.hk/files/page/51/Reference%20Material%20on%20Safety%20Roles%20and%20Responsibilities_Eng.pdf

Golberg, D.E. (1989). Genetic Algorithms in Search, Optimization, and Machine Learning. Addison-Wesley 1989, 102, 36.

HKHA (2017). Site Safety Handbook.
https://www.housingauthority.gov.hk/mini-site/site-safety/common/resources/handbook/201603/HB_res_tcen.pdf

HKHA (2010). Good Practice Promotion Kit Lifting Operation of Tower Crane. *https://www.housingauthority.gov.hk/mini-site/site-safety/common/resources/article/pdf/publications/safety-handbooks-and-booklets/Publications-03e.pdf*

HK-Twf (2021). A Guide to Good Practice on Control and Management of Temporary Works, HK Temporary Works Forum.

Hyun, H., Park, M., Lee D. & Lee J. (2021). Tower Crane Location Optimization for Heavy Unit Lifting in Higg-rise Modular Construction. Buildings 2021, 11(3), 121. *https://doi.org/10.3390/buildings11030121*

Ingenia (2012). Building the Shard, Issue 52, September 2012.

Kaveh, A., Mahdavi, V. (2014). Colliding Bodies Optimization: A Novel Meta-heuristic Method. Comput. Struct. 2014, 139, 18–27.

LD (2001). Guidance Notes on Inspection, Thorough Examination & Testing of Lifting Appliances and Lifting Gear.
https://www.labour.gov.hk/eng/public/os/C/gear.pdf

LD (2002). Code of Practice on Safety Management.
https://www.labour.gov.hk/eng/public/os/manage.pdf

LD (2004). Safe Systems of Work.
https://www.labour.gov.hk/eng/public/os/D/SafeSystem.pdf

LD (2011). Code of Practice for Safe Use of Tower Cranes.
https://www.labour.gov.hk/eng/public/os/B/crane.pdf

LD (2017a). A Guide to the Factories and Industrial Undertakings (Lifting Appliances and Lifting Gear Regulations).

LD (2017b). Code of Practice for Safe Use of Mobile Cranes.
https://www.labour.gov.hk/eng/public/os/B/CoP_for_Mobile_Cranes_ENG.pdf

LegCo (2008). Paper for Legislative Council Panel on Manpower Safety in the Use of Tower Cranes on Construction Sites (LC Paper No. CB(2)2480/07-08(01)).
https://www.legco.gov.hk/yr07-08/english/panels/mp/papers/mp0708cb2-2480-1-e.pdf

Meng, L., Zhang, C., Ren, Y., Zhang, B., Lv, C. (2020). Mixed-integer Linear Programming and Constraint Programming Formulations for Solving Distributed Flexible Job Shop Scheduling Problem. Comput. Ind. Eng. 2020, 142, 106347.

Mok, K.H. (2021). Opportunities and Risks in MiC Construction Case Sharing: HKSTP, Innocell.

Monash University (2017). Handbook for the Design of Modular Structures.

Sangaiah, A.K., Tirkolaee, E.B., Goli, A., Dehnavi-Arani, S. (2019). Robust Optimization and Mixed-integer Linear Programming Model for LNG Supply Chain Planning Problem. Soft Comput. 2019, 24, 7885–7905.

Ser, E. (2021). Safety Measures of Lifting Operation and Heavy Machinery - the Hong Kong Housing Authority's Experience, Construction Safety Week 2021 Conference. *https://www.safetyweek.hk/CSW_2021/conference_ppt/pm/Emily_SER.pdf*

Tam, C.M., Tong, T.K.L., Chan, W.K.W. (2001). Genetic Algorithm for Optimizing Supply Locations Around Tower Crane. J. Constr. Eng. Manag. 2001, 127, 315–321.

Tang, W. (2019). Presentation Materials on Selection and Pricing of Tower Crane.

Treviño, C.A. (2017). Single Tower Crane Allocation Models Using Ant Colony Optimization, The University of Texas Rio Grande Valley: Ann Arbor, MI, USA, 2017.

APPENDIX A – LIST OF TOWER CRANE AND MOBILE CRANE MANUFACTURERS

	Manufacturer	**Country of Manufacturing**	**Hong Kong Agent**	**Business Contact**	**Tel.**	**Email**
1.	Liebherr	Germany	Liebherr-Singapore Pte. Ltd.	William Tang	28306990	william.tang@liebherr.com
2.	Potain	USA				
3.	Yongmao	Liaoning & Beijing, China	Yongmao Machinery (HK) Co. Ltd.	Kenji Wong	24884966	yongmao@yongmao.com.hk
4.	Terex Comedil	Switzerland				
5.	Sichen Construction Machinery	Sichuan, China				
6.	Zoomlion	Hunan, China				
7.	Useter	Shenyang, China				
8.	Wolff	Germany				
9.	Comansa	Spain				
10.	Kroll	Denmark				
11.	Favelle Favco	Malaysia				

APPENDIX B – FREQUENCY OF TEST, THOROUGH EXAMINATION AND INSPECTION OF TOWER CRANES AND MOBILE CRANES UNDER THE LALGR (AFTER LD (2011) AND LD (2017B))

Regulation No.	Testing & Thorough Examination	Testing	Thorough Examination	Inspection	Approved Form No.
5(3) 7B	during the preceding 4 years before use (includes the test of the automatic safe load indicator)				3
5(5) 7B	before use, after undergoing substantial repair, re-erection, failure, overturning or collapse (includes the test of the automatic safe load indicator)				3
5(1)			at least once in the preceding 12 months		5
7A 7B				within the preceding 7 days (includes the inspection of the automatic safe load indicator)	1
7E		after erection, removal to a new location, or adjustment of any component member (being a removal or adjustment which involves changes in the arrangements for anchoring or ballasting)	all the devices used for the anchoring or ballasting of the crane before the crane is erected		2
7G		after exposure to weather conditions likely to have affected the stability of the crane			2

Notes:
1. The requirements for testing/examination of lifting gear are not included in the table.
2. Reference should be made to the full text of the LALGR.
3. Repair includes renewal, alteration or addition and examples of substantial repair include replacement of wire rope, replacement of brake, alteration of boom length or jib length, changing of hook block, and any repairs on steel structure which may affect the integrity of the crane.

APPENDIX C – FREQUENCY OF TEST, THOROUGH EXAMINATION AND INSPECTION OF LIFTING GEAR (AFTER LD (2001) AND LD (2017A))

	Regulation No.	Testing & Thorough Examination	Testing	Thorough Examination	Inspection	Approved Form No.
Chains, Ropes and Lifting Gear (except a fibre rope or fibre-rope sling)	3 18(1)(d)	before use				6
Chains, Ropes and Lifting Gear	3 18(1)(e)			In the preceding 6 months before use		7

APPENDIX D – QUALIFICATIONS, EXPERIENCE AND TRAINING REQUIREMENT FOR PERSONNEL INVOLVED IN LIFTING OPERATION (AFTER LD (2011), LD (2017B), CIC (2010) AND CIC (2020))

<table>
<tr><th>Personnel</th><th colspan="2">Qualification, Experience, Training & Competences</th></tr>
<tr><td>Competent Examiner (合資格檢驗員）</td><td colspan="2">This means a person in relation to the carrying out of any test and examination required by the Factories and Industrial Undertakings (Lifting Appliances & Lifting Gear) Regulations (Cap. 59J) (LALGR), who is:

(a) appointed by the owner required by these regulations to ensure that the test and examination is carried out;
(b) a Registered Professional Engineer (RPE) registered under the Engineers Registration Ordinance (Cap. 409) in the Mechanical Engineering and Marine & Naval Architectural discipline; and
(c) by reason of his qualifications, training and experience, competent to carry out the test and examination.

(Regulation 3(1) of the LALGR)</td></tr>
<tr><td>Competent Person (合資格的人）</td><td colspan="2">This means a person in relation to any duty required to be performed by him under the LALGR, who is:

(a) appointed by the owner required by these regulations to ensure that the duty is carried out by a competent person; and
(b) by reason of training and practical experience, competent to perform the duty.

(Regulation 3(1) of the LALGR)</td></tr>
<tr><td>Competent Person for Tower Crane Erection, Dismantling & Height Alteration</td><td colspan="2">This means a Registered Skilled Worker of the trade “To carry out erection, dismantling, telescoping/climbing of tower crane, and the hoisting of materials, tools and equipment related to the aforesaid work” under the Construction Workers Registration Ordinance (CWRO) (Cap. 583), who has:

(a) at least 10 years of relevant experience;

(b) experience in operating tower crane in the same model line, or completed a familiarization training on the same model line;

(c) completed the following courses: (i) Safety Training Course for Construction Workers of Specified Trade (Silver Card Course) - Tower Crane Worker (Erecting, Dismantling, Telescoping & Climbing) (“EDTC Course”) offered by the Construction Industry Council Training Academy (CICTA); and (ii) Training for Tower Crane Competent Person (Erecting, Dismantling, Telescoping & Climbing) offered by CICTA; and

(d) completed the Certificate Course with Imbedded Certification Test for Derrick Crane Operator offered by CICTA if he is in-charge of erection or dismantling of a tower crane using derrick crane.</td></tr>
<tr><td>Competent Workman for Erection, Dismantling & Height Alteration of Tower Crane</td><td>Senior Workman</td><td>This means a Registered Skilled Worker of the trade “To carry out erection, dismantling, telescoping/climbing of tower crane, and the hoisting of materials, tools and equipment related to the aforesaid work” under CWRO who has:

(a) at least 4 years of related work experience;

(b) completed (i) the Safety Training Course for Construction Workers of Specified Trade (Silver Card Course A12 - Construction Materials Rigger) and (ii) EDTC Course organized by CICTA.</td></tr>
</table>

<table>
<tr><td></td><td>Junior Workman</td><td>This means a Registered General Worker under CWRO, who
(a) works only under the direct one-to-one supervision of a Senior Workman; and
(b) has completed the Rigger Course organized by CICTA.</td></tr>
<tr><td>Crane Operator</td><td colspan="2">This means a person who:
(a) has attained the age of 18 years;
(b) holds a valid certificate issued by the Construction Industry Council (formerly known as CITA) or by any other person specified by the Commissioner for Labour; and
(c) in the opinion of the owner, is competent to operate the crane by virtue of his experience.
(Regulation 15A of the LALGR)</td></tr>
<tr><td>Inspection & Testing Technician</td><td colspan="2">This means a person who has
(a) at least 4 years of experience in inspection and maintenance for mechanical parts of tower cranes, including apprenticeship training and on-the-job technical experience;
(b) technical or trade test certificates; and
(c) the Training Certificate of Routine Inspection and Maintenance of Tower Cranes issued by the CICTA.
or
(a) at least 8 years of experience in inspection and maintenance for mechanical parts of tower cranes, including apprenticeship training and on-the-job technical experience; and
(b) the Training Certificate of Routine Inspection and Maintenance of Tower Cranes issued by the CICTA.</td></tr>
<tr><td>Lifting Safety Supervisor</td><td colspan="2">This person is the leader of the lifting team ensuring that the lifting team knows about the lifting plan and takes all practical steps to implement the lifting plan. This person:
(a) should be sufficiently experienced and ability; and
(b) preferably has completed the safety training on lifting supervision (e.g. the HKIC’s Certificate training course for Lifting Safety Supervisor).</td></tr>
<tr><td>Owner (擁有人)</td><td colspan="2">This includes, in relation to any lifting appliance or lifting gear, the lessee or hirer thereof, and any overseer, foreman, agent or person in charge or having the control of management of the lifting appliance or lifting gear and, in the case of a lifting appliance situated on or used in connection with work on a construction site, also includes the contractor responsible for the construction site.</td></tr>
<tr><td>Project Engineer</td><td colspan="2">This means
(a) the Registered Structural Engineer (RSE) appointed under Section 4 of the Buildings Ordinance (Cap. 123) (hereafter referred to as BO) for private project(s);
(b) a competent person whose appointment is, subject to prior agreement of the Building Authority, to take up the responsibilities and duties of a RSE for project(s) with exemption granted by the Building Authority from the procedures and requirements relating to the appointment of a RSE under Section 4 of the BO (e.g. for MTR projects);</td></tr>
</table>

	(c) the engineer(s)/supervising officer of similar capacity for Housing Authority project(s); (d) the engineer(s)/supervising officer as specified in the works contracts for public works projects; (e) (e) the independent checking engineer(s) of similar capacity appointed by the Principal Contractor at the request of the government departments for public works project(s).
Registered Contractor (RC)	This means a firm on the registers maintained under Section 8A of the Building Ordinance (BO) (Cap 123), and appointed to carry out building works or street works on a site.
Registered Professional Engineer (RPE)	This means a person whose name is on the register of registered professional engineers established and maintained under section 7 of the Engineers Registration Ordinance (Cap 409).
Registered Safety Officer (RSO)	This means a person registered under Regulation 7 of the Factories and Industrial Undertakings (Safety Officers and Safety Supervisors) Regulations (Cap. 59Z).
Registered Structural Engineer (RSE)	This means a person registered on the Structural Engineers' Register kept under Section 3(3) of the Buildings Ordinance (BO) (Cap. 123).
Rigger	This person is responsible for loading and unloading the load from the crane, and using the correct lifting gear and rigging method according to the lifting plan. This person: (a) has attained the aged of 18 years; (b) be fit with particular regard to eyesight, hearing and reflexes; (c) be agile and have the physique to enable him to handle lifting tackle; (d) has completed training on the principles of using general rigging (e.g. Safety Training Course for Construction Workers of Specified Trade (Silver Card Course A12 - Construction Materials Rigger) and be able to establish weights and judge distances, heights and clearances; (e) be capable of selecting tackle and lifting gear as well as rigging method suitable for the loads to be lifted; (f) fully understands the hand signals and radio communication signals used by the lifting team; (g) understands the signal code and is able to give clear and precise signals; (h) be capable of directing the movement of the crane and load in such a manner as to ensure the safety of personnel and plant; and (i) fully understands the radio/tele-communication signals between the parties concerned.
Safety Supervision Personnel Technically Competent Person (TCP) T5/T3	This means the TCP who possesses the academic or professional qualifications and experience of building works or street works that satisfy the requirements for a TCP set out in the Code of Practice for Site Supervision for a particular type of site supervision or management tasks (BD, 2021). TCP T3 should preferably have completed the HKIC's Certificate Course in MiC.
Signaller	This is the person responsible for transmitting the signal of the rigger to the crane operator, and the crane movement. This person: (a) has attained the aged of 18 years; (b) be fit with particular regard to eyesight, hearing and reflexes;

	(c) has completed training on general signaling principles and practices (e.g. Safety Training Course for Construction Workers of Specified Trade (Silver Card Course A12S - Rigger and Signaller) or Signaller for Hoisting Operations at Construction Sites course; (d) understands and is familiar with the hand signals used by the lifting team; (e) is able to clearly and accurately deliver the instructions to the rigger; and (f) be easily identifiable to the crane operator (e.g. by wearing 'high-visibility' clothing, or other means).
Specialist Contractor for Erection, Dismantling & Height Alteration of Tower Crane	This means a firm registered under the Designated Trade of S10 Tower Crane (Erection, Dismantling and Altering Height) of the Register of Specialist Trade Contractors (RSTC) administered by the CIC and appointed to carry out erection, dismantling and height alteration of a tower crane. The firm should: (a) directly employ at least one (1) Competent Person; (b) directly employ at least three (3) Senior Workmen; (c) understand the Chinese version of the method statement; (d) possess relevant experience and sufficient technical capability in telescoping/climbing, erection, dismantling and relocation of tower cranes; and (e) compile and maintain accurate safety records. Note: The Designated Trade of S10 Tower Crane includes transporting, erecting, dismantling, altering height of tower crane (except renting and operating), and the site lifting operations. Two courses related to the safety use of cranes are provided by the Hong Kong Institute of Construction (HKIC), namely Certificate Course in MiC for Foreman[33] and Professional Certificate Course in MiC for Project Managers and Clerks of Works[34]. In the courses, the topics of work arrangement and safety use of tower crane, lifting and installation of modular units, etc., are provided.
Supervising Engineer	This means a person who has: (a) an engineering degree of relevant discipline or an engineer with the qualification of RPE/ MHKIE or equivalent; (b) not less than 4 years of related working experience (1 year of related working experience means 1 erection, 4 telescoping/ climbing and 1 dismantling in 12 months); (c) the capability in administering the "Hold Points" on critical parts; (d) the capability in communicating with the Competent Person and the crane operator throughout the operation and is empowered to stop work if necessary; and (e) the capability to conduct a visual inspection on the parts of a tower crane to ensure that they are in good working order before commencement of any operations.

[33] https://spdc.hkic.edu.hk/en/course_search_detail?courseId=71
[34] https://spdc.hkic.edu.hk/en/course_search_detail?courseId=72

APPENDIX E – REPORT FOR RISK ASSESSMENT (AFTER CIC (2010))

A report for risk assessment should consist of the following sections –

(a) introduction;
(b) hazard assessment;
(c) method statement;
(d) record of key personnel; and
(e) manufacturer's manual for tower crane.

(A) Introduction

This section should cover –

(a) purpose of the risk assessment report;
(b) scope and detailed description of the project; and
(c) operations covered by the report.

(B) Hazard assessment

This section should cover the hazards identified taking into account all relevant matters including –

(a) preparation work
  - deployment of crew for work supervision;
  - checks on the suspension points of various accessories (items should be specified);
  - checks on the lifting appliances and lifting gears (items should be specified);
  - operating frequencies of walkie-talkies;
  - checks on hand tools and fall arresting stripes;
  - checks on full body harness;
  - location of the exclusion zone;
  - checks on personal protective equipment;
  - storage of material;
  - safety training;
  - wind speed monitoring and the maximum allowable wind speed; and
  - arrangement of the control ropes;
(b) work commencement procedures specifying the potential risk and mitigation measures of all procedures;
(c) work completion procedures including tests, examination and certification; and
(d) contingency plan for emergencies.

(C) Method statement

The method statement should be drawn up in consultation with the Competent Person, the Registered Safety Officer and other persons concerned and should clearly define the procedures for every step of the operations. It should be issued to the working crew for effective compliance with the prescribed procedures.

The method statement should include –

(a) details of the construction site and construction works including a site layout plan;
(b) general safety measures for the works;
(c) pre-construction plan;

(d) operating procedures with key points illustrated by diagrammatic illustrations;
(e) personal protective equipment; and
(f) safety measures for the operation.

(D) Personal particulars of crew members

This section should list the personal particulars of –

(a) staff responsible for drawing up the method statement;
(b) members of the working crew –
    (i) Competent Person;
    (ii) (ii) senior workmen; and
    (iii) junior workmen.

Personal particulars should include the following –

(a) name of the person;
(b) position held;
(c) qualifications held (including certificates issued in accordance with statutory provisions); and
(d) year of experience.

(E) Manufacturer's Manual

A copy of the manufacturer's manual should be included in the risk assessment report.

APPENDIX F – GRADES OF CHAIN

Chain is a durable and versatile tool for lifting. The strength of a chain is designated by its Grade. The Grade of chain is determined by the mean stress in the chain at the minimum breaking load. The higher the grade, the smaller and lighter the chain for a given working load. The chain falls into two categories:

(a) Carbon steel chain. This is commonly used for tie down and container securement purposes. This type of chain is not recommended for lifting.

(b) Alloy steel chain. All graded alloy steel chain is recommended for lifting.

As seen in Figure F.1, a Grade 70 chain, which is made of carbon steel, is not recommended for lifting, whereas Grades 60, 80, 100 and 120 chains, which are alloy steel chains, are recommended for use in sling assemblies and lifting applications. However, chain slings made from alloy steel are not suitable for use in acidic environments because they can cause hydrogen embrittlement.

The five common types of chain used are:

	Grade	Name	Relevant Standard	Suitable for Lifting?	Description
	**G60**	G60 Stainless Steel	AS 2321 DIN 5688	✓	Grade 60 stainless steel chain can be used in different corrosive environments and at higher temperatures, which is typically used in pump stations and marine environments.
	**G70**	Grade 70 Transport Chain	AS 4344	✗	Also known as Transport Chain, Grade 70 chain is designed for use as a tie down chain or lashing for transportation. It has a gold chromate finish to help resist corrosion from continuous exposure to the elements and the rigors of road use. It cannot be used for lifting due to its brittle nature.
	**G80**	Grade 8 Grade 80 Grade T Alloy Chain	AS 2321	✓	Grade 80 (T) chain is designed for industrial lifting applications. It is made from alloy steel, hardened and tempered. It has a high resistance to impact and is the most economical of the three chain grade types that are suitable for overhead lifting.
	**G100**	Grade 10 Grade 100 Grade V Alloy Chain	AS 2321	✓	Grade 100 (V) chain is generally used for chain slings. It has a working load limit approximately 25% higher than that of a Grade 80 chain. It is manufactured from hardened and tempered alloy steels, and has a high resistance to impact and wear. It is now becoming the most common chain used for manufacturing chain slings.
	**G120**	Grade 12 Grade 120	N/A Must comply with AS 2321 or ISO 16877	✓	Grade 120 chain is specifically designed for extreme overhead lifting applications. It is an ultra-premium quality high strength alloy steel and has a working load limit that is approximately 50% higher than that of a Grade 80 chain, and 20% higher than that of a Grade 100 chain. It is typically used where manual handling or weight is a critical factor.

Figure F.1 – Common Types of Chain[35]

The following definitions are used to define the properties of a chain:

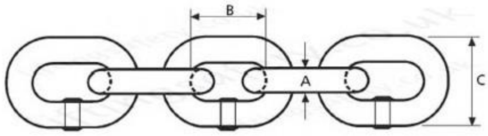
(a) Work Load Limit (WLL) is the maximum load which the chain is designed to sustain in lifting use. The mean stress at this load is 200 N/mm^2 (MPa) based on a factor of safety of 4.

[35] https://www.ranger.com.au/guides-and-publications/

(b) Manufacturing Proof Force (MPF) is the force to which during manufacture the chain is subjected to. The mean stress at this load is 500 N/mm^2 (MPa) which is 2.5 times the WLL.

(c) Minimum Breaking Load (MBL) is the minimum force which the chain must withstand before failure. The mean stress at this load is 800 N/mm^2 (MPa). The minimum elongation before failure is 20%.

For example, a Grade 8/80 lifting chain comes with a chain size 7 mm to 32 mm with a WLL of 1.5 tonne to 31.5 tonne, whereas a Grade 10/100 lifting chain comes with a chain size of 6 mm to 32 mm with a WLL of 1.4 tonne to 40 tonne, as shown in Figure F.2.



Grade 80					
A (mm)	B (mm)	C (mm)	Area (mm2)	WLL (kg)	Weight per metre (kg)
7	21	25.9	38.5	1500	1.1
8	24	29.6	50.3	2000	1.5
10	30	37.0	78.5	3159	2.2
13	39	48.1	132.7	5300	3.8
16	48	59.2	201.1	8000	5.8
20	60	74.0	314.2	12500	9.1
22	66	81.4	380.1	15000	11
26	78	96.2	530.9	21200	15.3
32	96	118.0	804.2	31500	23.2

Grade 100					
A (mm)	B (mm)	C (mm)	Area (mm2)	WLL (kg)	Weight per metre (kg)
6	18	25.9	28.3	1400	0.8
8	24	29.6	50.3	2500	1.5
10	30	37.0	78.5	4000	2.2
13	39	48.1	132.7	6700	3.8
16	48	59.2	201.1	10000	5.8
20	60	74.0	314.2	16000	9.1
22	66	81.4	380.1	19000	11.0
26	78	96.2	530.9	26500	16.1
32	96	118.0	804.2	40000	24.8

Figure F.2 – Properties of Chain

When more than one chain slings are used, the tension in the slings will depend on the angle made between the sling and the load, as shown in Figure F.3. The smaller the angle, the greater will be the tension developed in the sling. It is necessary to check that the tension developed in the chain sling lies within the WLL of the chain.

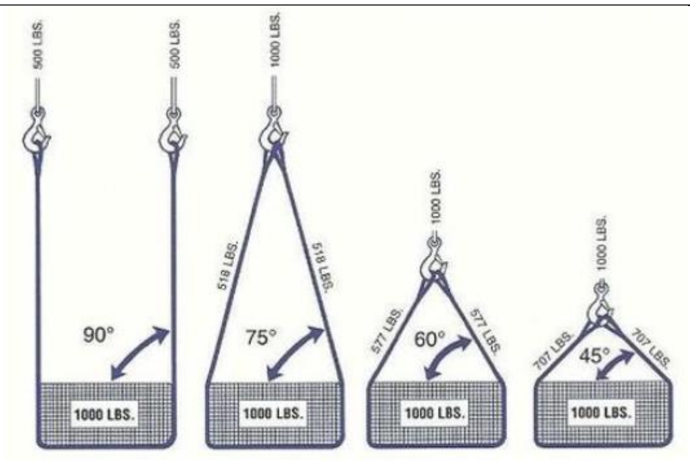


Figure F.3 – Computation of Tension in Chain Sling

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Thank you for reading this publication. To help us improve our future versions, we would appreciate your suggestions/feedback on the publication.

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Useful	❑	❑	❑	❑	❑
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	❑	❑	❑

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