Building Technology Research Institute
香港建築科技研究院
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Technical Specification for
Construction Drilling Robot





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Foreword

Construction drilling is a labour-intensive activity. With an ageing skilled workforce and a shortage of new entrants, the productivity and sustainability of manual drilling are increasingly constrained. Traditional drilling methods also face challenges in meeting increasingly stringent requirements for accuracy, consistency and quality.

Construction drilling robots offer a safer, more precise and repeatable alternative through controlled positioning, drilling and integrated safety functions. They improve the consistency and quality of drilling operations, reduce reliance on manual work at height, and contribute to a safer construction environment.

To facilitate wider adoption of robotic drilling technology, there is a need to align the diverse proprietary solutions offered by different vendors and establish clear and consistent specifications to streamline procurement and deployment. This document therefore sets out common technical and safety requirements for vendors, contractors and clients, providing a consistent framework for the selection and deployment of robotic drilling systems that meet defined performance and safety benchmarks.

Building Technology Research Institute and
The University of Hong Kong

Preface

Developed based on the Development Bureau Technical Circular (Works) No. 9/2025 - Adoption of Construction Robots, this specification provides a framework for deploying and operating construction drilling robots for on-site construction in Hong Kong.

This specification is applicable to public and private construction projects and sets out technical and safety requirements for standardized, safe and efficient drilling, supporting productivity, worker welfare and on-site safety.

This specification draws on Hong Kong construction safety regulations and emerging intelligent construction equipment specifications, setting minimum technical requirements while allowing innovation.

The Building Technology Research Institute and The University of Hong Kong jointly developed this specification. Contributions from the following organizations are gratefully acknowledged (in alphabetical order):

(a) Governmental Organizations / Industry Associations / Institutes

- Architectural Services Department, Government of the HKSAR
- Development Bureau, Government of the HKSAR
- Hong Kong Center for Construction Robotics
- Hong Kong Construction Association
- Hong Kong Construction Robotics Technology Society
- Hong Kong Construction Sub-Contractors Association
- Hong Kong General Building Contractors Association
- Hong Kong Housing Authority
- Hong Kong Institute of Construction
- Hong Kong Institution of Engineers
- Labour Department, Government of the HKSAR
- Occupational Safety and Health Council
- The Construction Industry Council
- The Hong Kong Polytechnic University
- The Hong Kong University of Science and Technology
- The Real Estate Developers Association of Hong Kong
- The University of Hong Kong

(b) Corporates

- CSC Robotic Engineering Ltd.
- Hilti (Hong Kong) Ltd.
- Shanghai Jikezhu Technology Co., Ltd.
- Zhejiang Dingli Machinery Co., Ltd.

The feedback from the aforementioned organizations is instrumental in shaping both the standards and the procedures outlined in this specification.

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The University of Hong Kong

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1 Overview

1.1 On top of statutory and contract requirements applicable to construction plant, machinery, and electrical equipment, this specification sets out minimum requirements for safe, repeatable and verifiable drilling-robot operation on construction sites.

1.2 The specification covers product capability, site deployment, operating modes, drilling performance, safety functions, environmental controls, exposure of workers, electrical and battery safety, operator competence, site acceptance, inspection, maintenance and records.

1.3 This specification establishes a two-tier compliance framework:

(a) **Essential Requirements**: Mandatory requirements that shall be enforced through inspections, compliance checking and quality assurance.

(b) **Best Practices**: Recommended measures that can enhance system performance.

2 Extent of Application

2.1 This specification applies to robotic or automated systems used for on-site construction in Hong Kong to locate and drill installation or fixing holes, including anchor and fixing holes, in building and civil-engineering elements made of materials the system is declared capable of drilling.

2.2 A construction drilling robot may be fixed, relocatable or mobile. It may use remote-controlled, semi-automated or self-navigation functions within the operating modes declared by the Vendor.

2.3 This specification does not apply to hand-held drilling tools, piling or foundation drilling, geotechnical investigation drilling, soil-nail or ground-anchor drilling, ground improvement or stabilization drilling, mining, tunnelling, oil or gas well drilling, horizontal directional drilling or utility boring.

3 Effective Date

3.1 This specification shall take immediate effect.

3.2 The specification shall be reviewed and revised from time to time upon technological advancement or regulatory amendment in the future.

4 Effect on Existing Specifications

4.1 This specification shall be read with applicable Hong Kong legislation and standards listed in Section 8, contract documents, project specifications, approved fixing-system requirements and manufacturer instructions.

4.2 This specification does not reduce any statutory duty. Where requirements conflict, applicable statutory requirements and any stricter contract, fixing-system, safety and health or manufacturer requirement shall take precedence.

5 Introduction

5.1 Traditional drilling exposes workers to repetitive strain, dust and respirable silica, noise and hand-arm vibration. Work at height or overhead increases fall risk and makes a stable working position harder to maintain. These exposures worsen fatigue, reduce situational awareness and increase musculoskeletal and respiratory risks.

5.2 Construction drilling robots mechanize or automate part of the drilling task, reducing worker exposure to hazards and improving hole-positioning consistency.

5.3 Vendors offer different robot designs, operating methods and automation levels. This specification provides a common basis for evaluating and comparing these systems and sets out the technical and safety requirements for their safe and effective deployment and operation.

6 Terms and Definitions

No.	Term	Definition
6.1	Automatic Operation	Operation in which the robot carries out a defined movement or drilling sequence automatically within stated operating limits after an authorized start.
6.2	BIM Compatible	Capable of receiving or using drill hole data from a BIM-based project workflow through a documented interface, file exchange or conversion method.
6.3	Client	Project owner or its appointed representative responsible for defining project acceptance requirements and accepting the robot for project use.
6.4	Construction Drilling Robot	Robotic or automated machine system used to locate and drill installation or fixing holes in construction elements, including holes for anchors and fixings, in materials the system is declared capable of drilling, with or without remote-control or mobile functions.
6.5	Drill Hole Data	Approved information defining a planned hole, including its identifier or reference, target position, diameter, depth, direction where specified and revision or source reference.
6.6	Drilling Cycle Time	Time from the stated start of a drilling cycle to the stated end of that cycle.
6.7	Drilling Position Accuracy	Difference between the centre of the completed drilled hole and the reference target hole location at the specified measurement surface.
6.8	Exclusion Zone	A defined area from which personnel and obstacles shall be excluded during automatic operation.
6.9	Hazard Zone	Area in or around the robot where a person may be exposed to a hazard from robot movement, drilling, rotating tools, falling objects, dust or other work activities.

No.	Term	Definition
6.10	Manual or Local Control	Direct control at or near the robot used for set-up, jogging, teaching, maintenance or recovery. It is not a production drilling mode under this specification.
6.11	Operating Limits	Declared limits for materials, hole sizes, drilling directions, reach, speed, load, floor conditions, clearances, environment and power.
6.12	Operating Zone	Area in which the robot moves, positions itself or carries out drilling work.
6.13	Operator	Trained, competent and authorized person controlling or supervising the robot.
6.14	Powered Travel	Movement of the robot base under its own power, including travel, turning and repositioning.
6.15	Pre-Operation (PO) Check	Recorded site checks, demonstrations, measurements and evidence review confirming applicable requirements before routine project use.
6.16	Productivity	The number of accepted holes divided by the actual processing time under the declared operating condition. It is the quantitative indicator of robot work efficiency. Actual processing time is the sum of the recorded drilling-cycle times for those holes.
6.17	Purchaser	Contractor, subcontractor, buyer or deploying party responsible for deployment, operating zone preparation, site services and safe working arrangements.
6.18	Reference Point	Physical or digitally defined point used to locate or verify one or more drilling positions.
6.19	Reference Target Hole Location	Hole-centre position defined before drilling by an approved and traceable setting-out or reference method and used to assess the completed hole position.
6.20	Remote-Controlled Operation	Operation in which the Operator continuously controls robot movement or a drilling function from a separate control device or location.

No.	Term	Definition
6.21	Robot Configuration	Configuration used for assessment, including robot model and serial number, software or firmware, operating mode, tooling, sensors, positioning equipment, dust controls and power arrangement.
6.22	Safe State	Condition in which hazardous robot movement or drilling is stopped or otherwise controlled so that the identified risk is reduced to an acceptable level.
6.23	Safe-Working Procedure	Documented site-specific instructions provided by the Purchaser, based on the risk assessment, for carrying out the robot's site activities safely.
6.24	Self-Navigation	Mobile operation in which the robot travels to a selected location without continuous steering by the Operator.
6.25	Semi-Automated Operation	Operation in which the Operator initiates, authorizes or performs part of the task and the robot automatically performs a defined part of the movement or drilling sequence.
6.26	Vendor	Supplier, manufacturer or authorized representative responsible for the robot system and the technical information, evidence, instructions, training or support required by this specification.

7 Technical Specification for Construction Drilling Robot

Section 7 sets out the technical requirements. **Annex A** provides supporting checks and verification methods and **Annex B** outlines the deployment workflow. The annexes do not add to or override the requirements in the main clauses. **Section 8** lists the normative references.

7.1 General Requirements

Essential Requirements

Scope and Vendor Obligations

7.1.1 The robot shall be suitable for its declared construction drilling use and operated in the accepted configuration within its operating limits. The Vendor shall provide product information and evidence demonstrating compliance.

7.1.2 The Vendor shall identify all system equipment and any other equipment needed for safe drilling, including the base or platform where provided, positioning mechanism, drill and tooling, dust-control equipment, sensors, operator interface, power equipment and safety devices.

7.1.3 The Vendor shall declare intended and excluded uses, supported materials and drilling orientations (including floor, wall, ceiling/overhead, angled and curved drilling), hole-size and depth ranges, safe maximum operational reach of the robot arm or positioning mechanism, operating range, drilling reaction forces and torques (including dynamic effects), power requirements, site conditions and other operating limits for the supplied configuration and intended operating conditions. The Client shall define project-specific requirements before procurement or the pre-operation (PO) check.

Safety-Related Design and Risk Controls

7.1.4 The Vendor shall provide a documented risk assessment using ISO 12100 as guidance for hazard identification, risk assessment and risk reduction. The assessment shall address hazards and risks affecting the Operator’s safety and health, the operating zone and its surroundings during transport, set-up, movement, drilling, tool change, cleaning, maintenance, disassembly and foreseeable abnormal conditions.

7.1.5 Before operation, all parts, guards, covers, fasteners, hoses, cables and connectors shall be securely installed and connected, with no visible deformation, cracks, corrosion, leakage, missing or loose components or damaged edges affecting safe operation, drilling accuracy or any declared

function. Fixed or movable guards shall prevent exposure to hazards during normal operation and foreseeable intervention, including at shafts, gears, drive belts or linkages. Drill-assembly guarding shall comply with 7.7.7.

7.1.6 Where the system includes an industrial robot or manipulator within the scope of ISO 10218-1, the Vendor shall provide evidence addressing the applicable requirements for it and its controller, in particular Sections 4 and 5. Mobile-platform hazards shall be risk-assessed separately.

7.1.7 Safety-related control functions shall achieve the performance required by the risk assessment. The Vendor shall provide configuration-matched conformity, test or validation evidence for these functions.

Residual Risks

7.1.8 The Vendor shall identify residual risks, restrictions and site controls needed for safe use in the instructions supplied with the robot.

Best Practices

7.1.9 Where relevant to the supplied robot application, integration verification against applicable principles of ISO 10218-2 should be provided.

7.2 Hardware and Performance

Essential Requirements

Capability and Depth Control

7.2.1 The Vendor shall state supported drilling methods and materials. The robot shall support nominal drilling diameters from 6 mm to 16 mm and adjustable depths reaching at least 100 mm. The Vendor shall declare supported discrete diameters, diameter/depth combinations and restrictions for the supplied configuration.

7.2.2 Drill bits, holders and adapters shall be suitable for the drilling task, compatible with the robot and the approved fixing or anchoring requirements where applicable, and securely retained during operation. Damaged, excessively worn or unsuitable drill bits shall be removed from service.

7.2.3 The drilling system shall provide depth feedback by measuring or deriving each completed-hole depth and displaying it to the Operator or recording it.

7.2.4 Completed-hole depth shall not be less than the approved required depth (tolerance -0 mm). Permitted over-depth shall comply with the approved fixing or anchoring system or Client-approved project requirement. For the PO check, completed-hole depth shall be verified by a suitable independent measurement method.

Anomaly Detection and Response

7.2.5 The robot shall detect abnormal drilling resistance, including reinforcement contact or tool jamming, by force sensing or another validated method such as torque or motor-current sensing.

7.2.6 Detection of an abnormal drilling condition under 7.2.5 shall trigger the safety response under 7.3.8. Restart shall require Operator assessment and deliberate authorized action under 7.7.3.

Best Practices

7.2.7 Where automatic tool changing is provided, secure tool engagement and the failure response should be verified. A failed or incomplete tool change should prevent automatic drilling until the condition is corrected.

7.3 Site Preparation and Robot Movement

Essential Requirements

Platform Data and Site Preparation

7.3.1 The Vendor shall state the robot dimensions, mass, required clearances, transport configuration and any floor-loading or stability limits relevant to site use. The robot shall be secured against unintended movement during transport.

7.3.2 Before deployment, the Purchaser shall check the access route and operating zone for floor capacity, clearances, headroom, openings, loose materials, cables and other hazards that may affect safe movement or stability. Both shall be kept tidy and adequately lit for safe movement, inspection and supervision. Where deployment involves work in a confined space within the scope of Cap. 59AE, the Purchaser shall ensure that applicable requirements of the Factories and Industrial Undertakings (Confined Spaces) Regulation and the Labour Department Code of Practice for Safety and Health at Work in Confined Spaces are met.

7.3.3 The operating zone for drilling and travelling shall have an inclination below 1:10 and no step or level difference exceeding 20 mm. Any stricter Vendor limit shall apply. For robots capable of powered travel, the Vendor shall declare the rated travel gradient and obstacle-crossing capability, including load, speed, direction and surface conditions. The Vendor shall declare that the supplied robot configuration is capable of safe operation under the relevant site conditions and within its declared operating limits.

Stability and Access

7.3.4 The robot base shall remain stationary during drilling, with any required stabilizers, outriggers or brakes correctly set before drilling starts.

7.3.5 Whenever hazardous robot operation is enabled, the Purchaser shall maintain fully fenced, access-controlled operating and exclusion zones covering the full operating range and foreseeable fall zone, with unobstructed access and egress. Conspicuous signs around the zones shall identify the operating zone and robot operation in simple Traditional Chinese, English and other languages understood by affected workers where required. The site layout and emergency escape route shall be displayed where applicable.

7.3.6 Access platforms, MEWPs, scaffolds and temporary work platforms shall meet applicable legal, inspection and site-safety requirements and manufacturer instructions, with MEWP operation and protective measures

complying with the Labour Department Guidance Notes on Safe Use of Mobile Elevating Work Platforms.

For platform-supported robots:

(a) Completion of the platform's required inspections, examinations and tests, and the validity of any required certificates, shall be confirmed.

(b) For the installed platform-robot arrangement, secure fixation and combined strength and stability, including mountings, any stabilizers and contacted structures, shall be verified over the intended operating envelope against all reasonably foreseeable forces, reaction forces and impact loads from robot operation (including rotation, swinging and drilling reaction).

(c) No worker shall remain on the platform during robot operation.

(d) An interlock or other validated control shall prevent robot operation while the platform is travelling, changing elevation or outside the verified stable operating limits.

(e) While the system is braced against a wall or ceiling slab, the control shall prevent platform movement that could dislodge the stabilizers or overload the system or contacted structure.

(f) Loss of required stabilizing contact shall trigger the safety response under 7.3.8.

7.3.7 For inter-floor or inter-level robot transport by site lift, builders' lift, hoist or other lifting or transport equipment, the Purchaser shall confirm suitability for the robot mass and dimensions, use within certified or stated capacity, and compliance with applicable legal requirements.

Abnormality Protection and Powered-Travel Safety

7.3.8 Abnormality sensing and protection shall remain active in all operating and set-up modes whenever the associated hazard can arise. A detected safety-affecting fault or abnormality shall trigger an Operator warning and automatic stopping of the affected hazardous movement or drilling, or another validated safe state, without creating a further hazard.

7.3.9 Powered travel shall remain within the Vendor-declared speed and protective separation limits from persons, obstacles and surfaces for the accepted configuration. Transport and operating speeds shall be stated separately where different. Under different travel modes:

(a) **Remote-controlled travel:** The Operator shall control travel in accordance with 7.4.4 and stop before unsafe contact or breach of the declared protective separation limits. Proximity sensing and Operator warning are Best Practice under 7.4.8.

(b) **Automatic powered travel (self-navigation and other travel continuing without hold-to-run control):** Detection of a person or obstacle by the non-contact protective sensing under 7.4.6 shall trigger automatic stopping of hazardous movement before unsafe contact or breach of the declared protective separation limits. Applicable ISO 3691-4 protective stopping requirements shall be verified where the mobile platform is within its scope.

7.3.10 The following braking, stopping and stability requirements shall apply:

(a) A robot with powered travel shall have a braking system or equivalent function to slow, stop and hold or restrain it under the accepted configuration, load, route and surface conditions.

(b) Applicable stops under 7.3.8, 7.3.9 and 7.4.4 and manual emergency stopping shall meet the stopping-distance and stopping-time limits under those conditions. The Vendor shall declare these limits and verify compliance at the PO check.

(c) Powered-travel tests shall use suitable test objects, not people as collision targets.

(d) The robot shall remain stable during powered travel, positioning, drilling and protective or emergency stopping, including under foreseeable drilling reaction forces. Stability-related operating limits shall be declared and verified for the accepted configuration.

Best Practices

7.3.11 Where permitted by the Vendor, the robot should be transported in its normal upright position, without dismantling, re-assembly, lying down, abnormal tilting or removal of any of its components.

7.3.12 For platform-supported robots, the Purchaser should obtain an engineering assessment and inspection report by an appropriately qualified Registered Professional Engineer (RPE) before use, covering:

(a) The installed platform-robot arrangement, verification results under 7.3.6 and supporting strength and stability calculations, taking account of the operating-zone conditions and applicable Vendor limits under 7.3.3, including declared powered-travel capabilities where applicable.

(b) Operating limits and conditions requiring reassessment.

7.3.13 Additional stabilization against suitable adjacent walls or ceiling slabs should use purpose-designed systems, including third-party systems, supported by the RPE report under 7.3.12 and, for MEWP-supported robots, approved by the MEWP manufacturer for the proposed configuration.

7.4 Operating Modes and Supervision

Essential Requirements

Operating Arrangements and Supervision

7.4.1 The following operating and supervision requirements shall apply:

(a) The Vendor shall declare travel, positioning and drilling arrangements, including the controls, functions and supervision for each.

(b) The robot shall support at least one accepted remote-controlled or automatic drilling workflow with required safety functions active.

(c) During powered travel, positioning or drilling, the Operator shall continuously supervise the robot and be able to stop hazardous movement or drilling immediately.

(d) Only one operating mode shall be active at a time. Mode selection shall use a lockable selector or equivalent authorized access control and shall not initiate hazardous movement.

7.4.2 Manual or local control shall be limited to set-up, jogging, teaching, maintenance or recovery, not production drilling. Moving a non-powered robot base manually or by separate site equipment before drilling does not constitute powered travel.

7.4.3 Fully automated operation: Where the robot uses self-navigation or automatic positioning and performs an authorized automatic drilling sequence, the common supervision requirements in 7.4.1 shall apply.

7.4.4 Semi-automated operation with remote-controlled set-up: During powered travel before automatic drilling, the Operator shall be on the same floor as the robot, keep the robot in clear view and hold the travel control continuously (hold-to-run). Travel shall stop when the control is released or control communication is lost.

7.4.5 Semi-automated operation with fixed or externally repositioned base: Where the base is fixed or moved into its work position manually or by separate site lifting or transport equipment, rather than by its own powered travel, it shall be secured and stable before drilling. Where a mobile elevating work platform (MEWP) or other mobile platform supports the robot, 7.3.6 shall apply.

Powered-Travel Sensing and Safety Response

7.4.6 During automatic powered travel, the robot shall have active non-contact protective sensing to detect persons and obstacles. The Vendor shall declare

sensing range, coverage, field of view and limitations. Abnormality and automatic protective-stopping responses shall comply with 7.3.8 and 7.3.9 respectively. This travel-sensing requirement does not apply to robots without powered travel or to remote-controlled travel under continuous Operator supervision and hold-to-run control in accordance with 7.4.4. For remote-controlled travel, this exemption shall be supported by the risk assessment under 7.1.4 and shall not waive the separation and stopping requirements in 7.3.9 and 7.3.10.

Best Practices

7.4.7 Automatic route replanning, where provided, should be verified at the pre-operation (PO) check by a functional demonstration involving the Operator, with Vendor support, under the Vendor-declared operating conditions. Representative scenarios should include obstacle avoidance, work-sequence changes and site-condition changes, as applicable. For robots with self-navigation, navigation performance may be tested using applicable methods in ISO 18646-2 or GB/T 38834.2.

7.4.8 For remote-controlled powered travel, the robot should have active non-contact proximity sensing to detect persons and obstacles and warn the Operator. The Vendor should declare sensing range, coverage, field of view and limitations.

7.5 Operator Interface and Control

Essential Requirements

Operator Interface and Control

7.5.1 At the active Operator interface on the robot controller, the Operator shall be able to identify the current operating mode, drilling status, warnings, alarms and stop conditions. The active hole's location or reference, diameter, depth and specified direction shall also be available to the Operator. The robot shall perform power-on self-diagnostics and warn the Operator of detected system faults.

7.5.2 The Operator interface shall allow the Operator to review and approve a configured task before execution, for example using a confirmation control. Automatic drilling or automatic powered travel shall start only after an authorized Operator confirms the task and deliberately initiates operation. Restart shall comply with 7.7.3. Operating commands shall be accepted from a single active point of control at a time. All required emergency-stop controls shall remain effective.

7.5.3 Emergency-stop controls and functions shall meet the following requirements:

(a) The robot shall have clearly visible, readily identifiable and readily accessible emergency-stop controls at the active remote controller, where provided, and at least one on the robot.

(b) The emergency-stop function shall be designed to achieve a controlled Stop Category 1 as defined in IEC 60204-1, following the applicable emergency-stop design principles of ISO 13850 or GB/T 16754.

(c) The safety-related control system implementing this function shall achieve Performance Level (PL) c or higher under ISO 13849-1, unless the risk assessment requires a higher Performance Level (PLr).

(d) A manual emergency stop during powered travel shall meet the Vendor-declared stopping performance under 7.3.10.

Network Access

7.5.4 The controller shall support authorized access over the Internet. The Vendor shall state how the connection is enabled, disabled and access-controlled. Loss of the external network connection shall not disable required safety functions.

7.5.5 Network access, remote-control commands, safety settings and drill hole data shall be protected against unauthorized access or changes through role-based permissions or equivalent access controls. Access permissions shall not allow required safety functions to be bypassed.

Best Practices

7.5.6 Where remote diagnostics, remote software support or automatic data transfer is provided, access should be authorized, logged where practicable and limited to the intended support or data function.

7.5.7 The Operator interface should support language displays in Traditional Chinese and English.

7.5.8 Where recovery of an interrupted drilling task is supported, the system should identify completed and outstanding holes or task steps before the Operator approves resumption. Resumption should require Operator review and deliberate authorization in accordance with 7.5.2 and 7.7.3.

7.6 Positioning and Accuracy

Essential Requirements

Drill Hole Data and References

7.6.1 Each hole shall have Client-approved drill hole data before drilling. The data shall include the target location, required diameter and depth, and drilling direction where specified. Changes shall be approved and recorded.

7.6.2 The target hole location shall be defined before drilling by an approved and traceable reference method. The reference may be a physical mark, surveyed point, verified coordinate or another approved setting-out method.

7.6.3 Before drilling, the robot shall identify the target hole using its normal positioning method and the approved drill hole data or reference. The Vendor shall state the positioning method and its operating limitations.

7.6.4 Automatic drilling for a hole shall be prevented when its required drill hole data are missing or invalid. The system shall give the Operator a clear warning or message.

Positioning and Accuracy

7.6.5 The centre of each accepted completed hole shall lie within a 5 mm-radius circular tolerance zone centred on the independently verified reference target hole location at the agreed measurement surface. Before the PO check, the number and distribution of test holes shall be agreed to cover the accepted project drilling positions, hole sizes and operating range. A single hole shall not be the sole basis for drilling-position acceptance.

BIM Compatibility

7.6.6 The robot shall be BIM compatible, with the Vendor stating the interface, file-exchange or conversion method used to receive or use drill hole data from the project BIM workflow. Before automatic execution, the Operator shall be able to review and approve the active task data and any imported or generated map, route or drilling sequence. For robots with self-navigation, the interface shall allow the Operator to define or confirm operating and exclusion zones, start and end points, and the work sequence.

Best Practices

7.6.7 Where digital drill hole data are used, the system should identify the active data set or revision before drilling starts.

7.6.8 Direct import of common CAD formats, including DXF or DWG, or drilling-plan formats should be supported where required by the project, provided

imported hole identifiers and parameters remain traceable to the approved drill hole data.

7.6.9 The robot should be able to utilise on-site environmental sensing/scanning to maintain a 3D digital twin model that visualises its operating status, including its real-time spatial location, drilling progress and travel path where applicable.

7.7 Operational Safety and Health

Essential Requirements

Emergency Stop Function

7.7.1 The emergency-stop function shall stop hazardous robot and drilling motion as quickly as practicable without creating a further hazard. Resetting the emergency stop shall not start movement or drilling.

Anomaly Response and Restart Prevention

7.7.2 Abnormality sensing and protection shall comply with 7.3.8. The Vendor shall identify relevant safety-affecting system abnormalities through the risk assessment under 7.1.4, including the applicable conditions listed in 7.7.4.

7.7.3 After an emergency stop, protective stop, power interruption, communication loss or critical fault, hazardous operation shall not restart automatically. Restart shall require deliberate authorized action after the hazard or fault condition has been cleared. Safety-critical control communication shall be monitored continuously, with loss beyond the Vendor-declared timeout established by the risk assessment triggering the applicable safe response.

7.7.4 A visual operation indicator shall show when powered movement or drilling is in progress and be perceptible to the Operator and persons in or approaching the controlled operating zone. Audible and visual alarm devices, such as flashing lights, shall warn the Operator and persons in or around the controlled operating zone of abnormal conditions. Required safety responses shall comply with 7.3.8 and, for power or battery conditions, 7.8.4. Abnormal conditions include, but are not limited to:

(a) Collision with surrounding obstacles or unbalancing motion.

(b) Power interruption or loss of control communication.

(c) Critical safety-sensor fault, LiDAR fault, navigation or positioning error.

(d) Steering, drive or motion-control faults, protective-stopping failure, or movement outside the approved operating zone.

(e) Motor overload.

(f) Overspeed.

(g) Manipulator fault.

(h) End-effector fault.

(i) Full dust container.

(j) Battery or charger fault, or overtemperature.

(k) Low battery level.

Fault Response and Verification

7.7.5 The Vendor shall state in the operation instructions the required response to relevant faults and abnormal conditions, including when to stop, isolate, inspect, reset or service the robot.

7.7.6 Where faults cannot safely be induced on site, the corresponding safety functions shall be verified by suitable simulation, safe functional demonstration or configuration-matched test/validation evidence. Laboratory IP, battery-abuse and environmental-chamber tests shall not be repeated on site.

7.7.7 The following protective measures shall apply:

(a) **Robot-arm contact protection:** The drilling robot shall be equipped with contact-sensing protective devices on its robot arm to protect against manipulator or end-effector collision, crushing and trapping hazards, in accordance with ISO 10218-1 where applicable. Upon detecting contact with an obstacle, the robot shall issue visual and audible warnings under 7.7.4, automatically stop all robot movement and drilling operations, and enter a safe state under 7.3.8.

(b) **Rotating-part guarding:** Reachable rotating drill-assembly parts shall be effectively guarded, in accordance with the Construction Sites (Safety) Regulations (Cap. 59I), during drilling. Where guarding the active drill bit is impracticable, a validated protective measure or risk-assessed controlled exclusion zone shall prevent access and provide equivalent protection under applicable machinery-guarding requirements.

(c) **Upward-reach guarding exception:** Upward-reach guarding may be omitted only where the relevant hazardous parts remain at least 2.7 m above every reasonably accessible standing surface, considering foreseeable access from platforms, ladders and adjacent structures, and the risk assessment confirms sufficient protection by distance under ISO 13857, Clause 4.2.1.2. Contact-sensing protection and all other required safeguards shall remain effective.

<u>Best Practices</u>

7.7.8 The robot should issue audible alarms to the Operator and persons in or approaching the controlled operating zone during its operations. Routine

operating sound may be omitted in a fully fenced, access-controlled operating zone where the risk assessment and applicable requirements permit. Required abnormal-condition alarms under 7.7.4 shall remain effective.

7.8 Power Supply, Electrical Safety, Battery and Charging

Essential Requirements

Power Supply and Electrical Protection

7.8.1 The Vendor shall state the power-supply arrangement and, as applicable, rated voltage, current or power, required earthing or protective conductor arrangement, battery type and voltage, approved charger and operating limits.

7.8.2 The electrical equipment of the robot shall comply with the applicable requirements of IEC 60204-1 or GB/T 5226.1 for the supplied configuration.

(a) Hazardous live parts shall be protected against accidental contact.

(b) Accessible conductive parts that could become live under a fault shall have protective bonding or equivalent fault protection.

(c) Suitable isolation, overcurrent protection and, where applicable, residual-current protection shall be provided for operating and charging modes.

7.8.3 For lithium cells or batteries:

(a) Rechargeable lithium cells or batteries within the scope of IEC 62619 shall meet its applicable safety requirements, supported by configuration-matched test or certification evidence from the Vendor.

(b) For lithium cells or batteries transported separately, packed with or contained in the robot, the Vendor shall provide the applicable UN 38.3 test summary for each tested cell or battery type, including the required manufacturer and test-laboratory particulars, together with transport classification, state-of-charge and packaging evidence applicable to the mode of transport.

Battery Safety and Status

7.8.4 The system shall show the Operator the power or battery status needed for safe operation. Battery-powered robots shall issue a low-battery warning when the remaining capacity reaches 20% or earlier. Low battery, battery or charger fault, overtemperature and impending power loss shall trigger the defined safe response before hazardous control is lost, with safety-affecting conditions handled under 7.3.8.

7.8.5 External power cables, plugs, connectors and charging equipment shall suit the supply and site conditions and shall be arranged to prevent electrical and trip hazards, water exposure and physical damage.

Cables and Charging

7.8.6 Charging arrangements shall meet the following requirements:

(a) Charging shall use the approved charger and Vendor-stated procedure in a location suitable for the site conditions.

(b) Where electrical installation work is required for the charging facility, it shall comply with the Electricity Ordinance (Cap. 406) and subsidiary regulations and be undertaken by appropriately registered electrical contractors and workers as required by law.

(c) Site-supply and charging installations within the scope of the EMSD Code of Practice for the Electricity (Wiring) Regulations shall comply with its applicable provisions, including Code 26K for construction or demolition works.

Best Practices

7.8.7 Where battery-powered, the robot should provide at least 4 hours of battery endurance without recharging under a declared representative duty cycle.

7.8.8 The Vendor should provide electromagnetic compatibility (EMC) test or conformity evidence appropriate to the declared site environment and supplied configuration. Where relevant, evidence should cover immunity and emissions under applicable product standards or generic standards such as IEC 61000-6-2 and IEC 61000-6-4, and support that foreseeable electromagnetic disturbance does not impair required safety functions or cause hazardous unintended operation.

7.9 Environmental and Worker Protection

Essential Requirements

Dust and Noise

7.9.1 Drilling dust shall be controlled throughout drilling at, or as close as practicable to, the active drill-bit/workpiece interface. Control measures shall use suitably positioned and maintained dust collection, local extraction, wet suppression or another validated method suitable for the task. Where container, bag or filter condition can reduce effectiveness, the system or work procedure shall identify servicing needs before effective dust control is lost. To prevent the inhalation of dust by the workers, the Purchaser shall establish and implement a regular cleaning and maintenance schedule for air filters, dust-collection containers and bags, as applicable, in accordance with the Vendor instructions. Dust-control and extraction systems shall be maintained in effective working order, and adequate site ventilation shall be provided and maintained.

7.9.2 Where drilling may expose workers or Operators to respirable silica or another hazardous air impurity, the work method and site controls shall comply with the current Hong Kong occupational exposure requirements such as the Occupational Exposure Limits. For details, refer to the Code of Practice on Control of Air Impurities (Chemical Substances) in the Workplace. Specialist workplace monitoring shall be arranged where required by the risk assessment, including assessment of workers' health risks and exposure, or by project requirements. Based on the assessment and monitoring results, appropriate measures shall be taken to prevent and control air impurities in the workplace.

7.9.3 Operators and other persons entering the operating zone shall wear suitable personal protective equipment, including eye and respiratory protection, as required by statutory duties or site rules.

7.9.4 The Vendor shall provide noise information for representative drilling and state the measurement conditions. Workplace noise exposure shall be assessed and controlled under the Factories and Industrial Undertakings (Noise at Work) Regulation. Suitable hearing protection shall be used where required by statutory duties or site rules.

Environmental Limits and Ingress Protection

7.9.5 The Vendor shall declare, with supporting manufacturer data or test evidence, the environmental limits for operation, storage and, where

applicable, charging, including ambient temperature, relative humidity and altitude. Differences between these limits shall be stated separately, together with applicable storage duration, battery state of charge and maintenance conditions.

7.9.6 Drilling tools shall be suitable for the specified site conditions and comply with the applicable electrical-safety requirements in Section 7.8 and the project specifications.

7.9.7 The robot shall not be operated in an explosion-risk environment unless the Vendor provides explosion-proof certification under IEC 60079, through an IECEx Certificate of Conformity for Explosive Atmosphere or flameproof reports certifying the robot's enclosure and electrical parts.

Best Practices

7.9.8 The robot's electronic control cabinets, battery packs, motors and manipulators, where provided, should have at least IP53 protection through individual or shared enclosures in accordance with IEC 60529 or GB/T 4208.

7.9.9 The robot should provide dust filtration to prevent the ingress of dust or other particles that could cause equipment malfunction.

7.9.10 The robot should be equipped with suitable filters with appropriate filtration effectiveness, such as Group H HEPA filters (H13 or H14) classified under BS EN 1822-1, in order to capture hazardous dust and prevent onsite personnel from inhaling airborne contaminants.

7.10 Inspection and Maintenance

Essential Requirements

Pre-delivery inspection

7.10.1 Before delivery of the robot to site, the Purchaser shall confirm project requirements and robot suitability and provide:

(a) A documented site-specific risk assessment identifying potential safety hazards and risks to the Operator and the surroundings of the robot's working area, following the risk-assessment and risk-reduction principles of ISO 12100, and the applicable industrial-robot requirements of ISO 10218-1 where relevant;

(b) A Safe-Working Procedure based on the risk assessment and Vendor instructions, covering arrival, unloading, site movement, set-up, operation, maintenance, dismantling, removal and emergency response, with reference to Annex B.

The documents shall be reviewed and updated as necessary after changes affecting safety.

7.10.2 Before delivery, the Vendor shall check the proposed robot configuration, required safety functions and conformity documents and provide the evidence needed for the Purchaser to confirm transport and site arrangements, with reference to the pre-delivery (PD) checklist in Annex A.1.

Pre-operation inspection

7.10.3 Before the pre-operation check, the Purchaser shall confirm site readiness and implementation of the controls under 7.10.1, including safe access, operating-zone controls, robot set-up and briefing of relevant personnel.

7.10.4 Before routine project use:

(a) The Operator shall conduct the PO check of the delivered and installed robot using Annex A.2, with Vendor support for model-specific tests. Where specialist checks or measurements are needed, they shall be performed by persons competent for the relevant work.

(b) The Purchaser shall organize site arrangements and checks.

(c) The Client shall define project-specific acceptance criteria and accept the recorded results only after failed requirements are corrected and re-tested.

Pre-use inspection

7.10.5 The Operator shall conduct the pre-use (PU) check of the robot and operating zone before each shift or use, and after relocation to another operating zone, material site-condition changes or any event that may affect drilling performance or a safety function, following the Vendor instructions, safe-working procedure under 7.10.1 and Annex A.3. Failed items shall be corrected and affected functions re-tested before use.

Inspection during operation and maintenance

7.10.6 The robot shall be inspected and maintained in accordance with the methods and intervals specified in the Vendor maintenance instructions. The Purchaser shall arrange the required inspections and maintenance. Following an event that may affect safety or drilling accuracy, the affected functions shall be checked before further use.

7.10.7 Safety devices, measurement equipment and accuracy-related functions shall be checked or calibrated where required by the maintenance instructions or acceptance method.

Post-maintenance inspection

7.10.8 After maintenance, repair or a change affecting safety or drilling accuracy, the Operator shall verify the affected functions before return to service in accordance with the Vendor instructions and applicable Annex A checks, covering safety-related controls, positioning and drilling accuracy, tooling retention, protective sensing, guarding and electrical protection where affected.

7.11 Documentation and Data Security

Essential Requirements

Product and Project Documents

7.11.1 The following documentation requirements shall apply:

(a) The Vendor shall provide a technical file identifying the robot model and serial number, system configuration, supported drilling capability, dimensions and mass, operating range, power arrangement, software/firmware and operating limits.

(b) Controlled technical documents shall carry suitable identification, including title or reference, issue date and revision/version, to distinguish current and superseded issues.

7.11.2 The Vendor shall provide operation and maintenance instructions covering:

(a) **Handling and deployment:** Lifting, handling, transport, storage and set-up, including approved handling/lifting points and methods, securing of movable parts and tooling, transport configuration and applicable storage/environmental limits.

(b) **Operation and safety:** Operation, operating modes, safety functions, emergency response, tool change, dust control, power and charging.

(c) **Inspection and servicing:** Inspection, maintenance and fault recovery under 7.7.5.

(d) **Site conditions and support:** Required site conditions and resources, and emergency contact or support arrangements where applicable.

7.11.3 The robot shall carry durable, legible identification or a nameplate in a readily visible position showing, as applicable, product name, model, unique serial or production number, manufacturer, year/date of manufacture and rated electrical information.

Records and Retention

7.11.4 Records shall cover the following, as applicable:

(a) Site-specific risk assessments and safe-working procedures, PO checks and re-tests, and pre-use checks.

(b) Training, refresher training, competency assessments, authorization and relevant Operator operation history.

(c) Inspections, maintenance, repairs, calibration and verification, including any RPE reports and manufacturer approvals obtained.

(d) Safety-related incidents and investigated stops.

(e) Approved changes affecting safety or drilling accuracy.

(f) Project drill hole data used for acceptance.

PO records shall identify the robot configuration, test conditions, results and evidence references.

7.11.5 Documents and records required by this specification shall be kept for at least 3 years from project completion, unless law or contract requires longer.

7.11.6 Where operational data logs are generated, including records of drill hole data, robot status and operating time, they shall be retained for at least 30 days from creation and shall be exportable as TXT, CSV or another readable project-approved format.

As applicable, the logs shall include:

(a) Operating mode, task start and end times, position or location reference.

(b) Active-hole identifier and parameters, and completion status.

(c) Warnings, alarms, protective stops and faults.

(d) Operator-authorized restarts.

7.11.7 Records shall be protected against unintended alteration or loss and shall remain retrievable for the required retention period. For electronic records, access and changes shall be controlled and traceable.

Best Practices

7.11.8 Productivity and drilling cycle time should be recorded during deployment where required by the Client. Productivity should be reported as accepted holes per process hour, calculated from the sum of recorded drilling-cycle times under declared conditions.

7.11.9 Where electronic records or robot configuration data are needed for operation, acceptance or traceability, suitable backup and recovery arrangements should be provided. Restored safety-relevant settings and approved drill hole data should be checked before automatic operation resumes.

7.12 Conformity Evidence

Essential Requirements

7.12.1 Conformity evidence shall meet the following requirements:

(a) The Vendor shall provide applicable safety, electrical, battery and environmental-protection evidence for the supplied configuration, using relevant test results, test-report extracts, declarations or other verifiable evidence.

(b) Any claimed or project-required IP rating shall also be supported by configuration-matched evidence. Where conformity or certification is claimed, the Vendor shall provide verifiable supporting evidence.

(c) Each evidence item shall identify the product, component or organization covered and, as applicable, its configuration, the relevant technical clause, referenced standard and scope.

(d) The same evidence may support several clauses where its scope is applicable.

Complete certificates or reports need not be submitted unless specifically required by this specification, applicable legislation or the contract.

7.12.2 For any radio transmitter within the State Radio Regulatory Commission (SRRC) type-approval scope, the Vendor shall submit a valid Radio Transmitting Equipment Type Approval Certificate for the radio components.

7.12.3 For radio transmitting equipment used in Hong Kong, the Vendor shall classify the equipment under the Hong Kong Telecommunications Equipment Evaluation and Certification (HKTEC) Scheme in OFCA I 421(24) Issue 8.

(a) For equipment under the Compulsory Certification Scheme, the Vendor shall obtain a certificate before marketing or use.

(b) For equipment under the Voluntary Certification Scheme, the Vendor shall submit an accredited test report/declaration and evidence of compliance with the Telecommunications Ordinance (Cap. 106).

Best Practices

7.12.4 For a robot or its component falling within the current CCC catalogue, the Vendor should submit evidence of valid CCC certification or completion of the applicable self-declaration route under CCC where that route remains permitted.

7.12.5 Where applicable, the robot should hold valid CR construction-robot certification of Mainland China under CR-1-08, together with the associated test report(s) to CR-1-08TS-01, CR-1-08TS-02 and CR-1-08TS-03 where relevant. The certificate should identify the exact model and scope and should be supported by the applicable CR technical-specification test reports.

7.12.6 Where applicable, the robot should bear CE marking, which is recognized in the European Economic Area market as a demonstration of compliance with applicable health, safety and environmental protection requirements. The Vendor should ensure that the manufacturer has completed the applicable conformity assessment, prepared the technical documentation, issued the applicable Declaration of Conformity and affixed CE marking.

7.12.7 The Vendor should hold a valid ISO 9001 Quality Management System Certificate issued by a certification body accredited for ISO 9001 certification, covering the Vendor's quality management system for its relevant product design, manufacture and supply activities.

7.13 Personnel Training

Essential Requirements

Operator Qualification and Trade Registration

7.13.1 The Operator shall meet the following qualification requirements:

(a) The Operator shall be trained and competent to operate the robot in accordance with the Construction Sites (Safety) Regulations requirements for mechanical equipment.

(b) The Operator shall hold valid construction-worker registration under the Construction Workers Registration Ordinance (Cap. 583), as required for the assigned work.

(c) Where drilling involves a designated trade division, the Operator shall hold valid skilled or semi-skilled registration for that division, unless the work is carried out under the instruction and supervision of a registered skilled or semi-skilled worker for that division in accordance with the applicable arrangements under Cap. 583.

Training, Assessment and Retraining

7.13.2 The Operator shall have received at least 16 hours of model-specific training covering theoretical and supervised practical instruction and a competence assessment under 7.13.3. Training shall cover the following aspects, including but not limited to:

Basic operational safety of Construction Drilling Robots, including:

(a) Introduction to the robot system and operating modes.

(b) Pre-construction planning and deployment, preparation of the operating zone and operating limits.

(c) Safety regulations and risk management, emergency stops and safety functions, abnormal conditions and recovery.

(d) Dust and noise controls, power and charging, pre-use checks and maintenance boundaries.

Practical operation, quality control and acceptance of Construction Drilling Robots, including:

(e) Full-process hands-on operation.

(f) Integrated use of positioning equipment, drilling tools and dust-control equipment.

(g) Preparation and verification of drill hole data, positioning, drilling and tooling.

(h) Quality inspection and acceptance requirements for completed-hole position, diameter and depth.

The Vendor or an authorized training party shall provide the training or an equivalent course of at least the same duration covering the robot model, relevant operating modes and the above aspects.

7.13.3 The following assessment and authorization requirements shall apply:

(a) The Operator shall have passed a competence assessment based on the specific robot model provided by the Vendor, covering at least the relevant operating modes, theoretical knowledge and practical skills.

(b) The training record and assessment result shall be documented.

(c) Upon successful completion of the assessment, the Vendor or an authorized training party shall issue a certificate specifying the name of the Vendor, robot model and authorized operating modes.

(d) The Operator shall not independently operate the robot in an operating mode not covered by the completed training and authorization.

7.13.4 The Operator shall complete refresher training at appropriate intervals recommended by the Vendor or an authorized agent. Records of the Operator's relevant operation history shall be documented. The Purchaser shall ensure that the Operator is competent to control and operate the robot on site.

7.13.5 Before entering a confined space, the Operator and relevant personnel shall comply with the qualification requirements stated in the Factories and Industrial Undertakings (Confined Spaces) Regulation (Cap. 59AE), and hold a valid certificate where applicable to the duties being carried out.

8 Normative References

The documents below apply only as specified in the relevant clauses of this specification. For undated references, including ISO, IEC, GB and GB/T standards, the latest edition and amendments apply. For dated references, the cited edition applies unless legislation or the contract requires otherwise.

1. Air Pollution Control (Construction Dust) Regulation (Cap. 311R);
2. Air Pollution Control Ordinance (Cap. 311);
3. BS EN 1822-1, High efficiency air filters (EPA, HEPA and ULPA) - Part 1: Classification, performance testing, marking;
4. Builders' Lifts and Tower Working Platforms (Safety) Ordinance (Cap. 470);
5. Construction Industry Council - Construction Workers Registration Ordinance Booklet;
6. Construction Sites (Safety) Regulations (Cap. 59I);
7. Construction Workers Registration Ordinance (Cap. 583);
8. CR-1-08, Implementation rules for CR certification of construction robots;
9. CR-1-08TS-01, Technical Specification for Safety of Construction Robots;
10. CR-1-08TS-02, Construction Robot - Electromagnetic compatibility - Generic standards - Immunity requirements and limits;
11. CR-1-08TS-03, Construction Robot - Electromagnetic compatibility - Generic standards - Emission requirements and limits;
12. Development Bureau - BIM Harmonisation Guidelines for Works Departments;
13. Development Bureau - Technical Circular (Works) No. 9/2025: Adoption of Construction Robots;
14. Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast);
15. Electrical and Mechanical Services Department - Code of Practice for the Electricity (Wiring) Regulations;
16. Electricity Ordinance (Cap. 406);
17. Electricity (Wiring) Regulations (Cap. 406E);
18. Factories and Industrial Undertakings (Confined Spaces) Regulation (Cap. 59AE);
19. Factories and Industrial Undertakings (Electricity) Regulations (Cap. 59W);
20. Factories and Industrial Undertakings (Guarding and Operation of Machinery) Regulations (Cap. 59Q);
21. Factories and Industrial Undertakings (Noise at Work) Regulation (Cap. 59T);
22. Factories and Industrial Undertakings Ordinance (Cap. 59);

23. GB 45943, Building construction machinery and equipment - Common safety requirements;
24. GB/T 12642, Industrial robots - Performance criteria and related test methods;
25. GB/T 13306, Plates;
26. GB/T 16754, Safety of machinery - Emergency stop function - Principles for design;
27. GB/T 20867.1, Robotics - Application specification for safety requirements - Part 1: Industrial robot;
28. GB/T 20868, Industrial robot - Application specification for performance test method;
29. GB/T 38244, General principles of robot safety;
30. GB/T 38834.2, Robotics - Performance criteria and related test methods for service robots - Part 2: Navigation;
31. GB/T 4208, Degrees of protection provided by enclosure (IP code);
32. GB/T 5226.1, Electrical safety of machinery - Electrical equipment of machines - Part 1: General requirements;
33. IEC 60079 series, Explosive atmospheres;
34. IEC 60204-1, Safety of machinery - Electrical equipment of machines - Part 1: General requirements;
35. IEC 60529, Degrees of protection provided by enclosures (IP Code);
36. IEC 61000-6-2, Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments;
37. IEC 61000-6-4, Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments;
38. IEC 62443-3-3, Industrial communication networks - Network and system security - Part 3-3: System security requirements and security levels;
39. IEC 62619, Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications;
40. ISO 10218-1, Robotics - Safety requirements - Part 1: Industrial robots;
41. ISO 10218-2, Robotics - Safety requirements - Part 2: Industrial robot applications and robot cells;
42. ISO 12100, Safety of machinery - General principles for design - Risk assessment and risk reduction;
43. ISO 13849-1, Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design;
44. ISO 13850, Safety of machinery - Emergency stop function - Principles for design;

45. ISO 13857, Safety of machinery - Safety distances to prevent hazard zones being reached by upper and lower limbs;
46. ISO 18646-2, Robotics - Performance criteria and related test methods for service robots - Part 2: Navigation;
47. ISO 19650-1, Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 1: Concepts and principles;
48. ISO 19650-2, Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 2: Delivery phase of the assets;
49. ISO 20607, Safety of machinery - Instruction handbook - General drafting principles;
50. ISO 3691-4, Industrial trucks - Safety requirements and verification - Part 4: Driverless industrial trucks and their systems;
51. ISO 4463-1, Measurement methods for building - Setting-out and measurement - Part 1: Planning and organization, measuring procedures, acceptance criteria;
52. ISO 7976-1, Tolerances for building - Methods of measurement of buildings and building products - Part 1: Methods and instruments;
53. ISO 7976-2, Tolerances for building - Methods of measurement of buildings and building products - Part 2: Position of measuring points;
54. ISO 9001, Quality management systems - Requirements;
55. Labour Department - A Guide to the Factories and Industrial Undertakings (Noise at Work) Regulation;
56. Labour Department - A Guide to the Provisions for Safe Use of Hoists under the Construction Sites (Safety) Regulations;
57. Labour Department - Air Monitoring in the Workplace;
58. Labour Department - Code of Practice for Safety and Health at Work in Confined Spaces;
59. Labour Department - Code of Practice on Control of Air Impurities (Chemical Substances) in the Workplace;
60. Labour Department - Guidance Notes on Factories and Industrial Undertakings (Noise at Work) Regulation;
61. Labour Department - Guidance Notes on Safe Use of Mobile Elevating Work Platforms;
62. Noise Control Ordinance (Cap. 400);
63. Occupational Safety and Health Ordinance (Cap. 509);
64. Occupational Safety and Health Regulation (Cap. 509A);

65. Office of the Communications Authority - OFCA I 421(24), Issue 8: Hong Kong Telecommunications Equipment Evaluation and Certification (HKTEC) Scheme;
66. State Administration for Market Regulation - Announcement No. 57 of 2025: Adjustment of Certification Modes for Certain Products in the Catalogue of Products Subject to Compulsory Certification;
67. Telecommunications Ordinance (Cap. 106);
68. United Nations - Manual of Tests and Criteria, Eighth Revised Edition, as amended by Amendment 1, subsection 38.3.

Annex A: Pre-delivery (PD), Pre-operation (PO) and Pre-use (PU) Checklists

This Annex provides supporting pre-delivery (PD), pre-operation (PO) and pre-use (PU) checklists and verification methods for **Section 7**. Factory or type-test evidence may be used where appropriate. PO checks include site demonstrations, measurements and evidence review before routine project use. The contract may require additional acceptance stages.

The Vendor shall supply product information and conformity evidence. The Purchaser shall organize site arrangements and checks. The Client shall define project-specific acceptance values and accept the PO record. Detailed responsibility allocation is not required for routine records unless the contract states otherwise.

A.1 Sample Pre-delivery (PD) Checklist

ID	Item	Acceptance Criteria / Requirement	Method
PD-01	Robot identification and configuration	Model, serial number, software/firmware, tooling and power configuration are identified and match the proposed supply.	Document review
PD-02	Technical and safety information	Operating limits, risk assessment, residual risks, operation instructions and maintenance instructions are available.	Document review
PD-03	Safety-function evidence	Available conformity/test/validation evidence covers the required safety functions, all intended operating and set-up modes and the supplied configuration, including abnormality protection under 7.3.8.	Document review
PD-04	Electrical, battery, IP and conformity evidence	(a) Applicable electrical, battery and environmental-protection evidence identifies the supplied components/configuration. (b) Claimed or project-required IP ratings and any claimed conformity or certification are supported by evidence under 7.12.1. (c) Applicable UN 38.3 test summaries for the tested lithium cell or battery type under 7.8.3 and Hong Kong radio-equipment evidence under 7.12.3 are available. (d) Evidence for the Best Practices in 7.12.4 to 7.12.7 is reviewed where claimed or required by the project.	Document review
PD-05	Drilling capability	Supported materials, hole sizes, depths, orientations and operating range cover the approved project drill hole data.	Document review

ID	Item	Acceptance Criteria / Requirement	Method
PD-06	Access and transport	(a) Robot mass/dimensions, access route, doorways and site lifts/hoists are suitable for delivery and inter-floor movement. Manufacturer-approved transport arrangements and securing against unintended movement are confirmed. Manufacturer-approved lifting/handling instructions and securing of movable parts and tooling under 7.11.2 are checked. (b) For robots capable of powered travel, the declared travel gradient and obstacle-crossing limits shall be checked against the intended access route and deployment.	Document review / visual
PD-07	Floor and operating zone	Floor capacity, clearances, headroom and operating zone conditions are suitable.	Document review / visual
PD-08	Operator qualification	Construction-worker registration, model-specific training/assessment, current authorization and competence, and applicable trade instruction/supervision arrangements are confirmed. The model/mode completion certificate under 7.13.3 and any required valid Certificate of Certified Worker under 7.13.5 are available.	Document review
PD-09	Project data	Approved drill hole data, reference-setting method and project acceptance values are available. The Purchaser's site-specific risk assessment and safe-working procedure under 7.10.1 shall be prepared before delivery to site.	Document review
PD-10	Power and charging	Required supply, charger and charging location are available and compatible with the robot.	Document review / visual

A.2 Sample Pre-operation (PO) Checklist

ID	Item	Acceptance Criteria / Requirement	Method
PO-01	Identification and configuration	Robot configuration matches the approved submission.	Visual / document review
PO-02	Operating zone and access	(a) Floor capacity, access, headroom, clearances, openings and site hazards are acceptable. (b) The operating zone is fully fenced with controlled access under 7.3.5. (c) For platform-supported robots, confirm applicable inspection/certification, secure fixation, combined strength and stability, the verified working condition and required controls under 7.3.6. Where the project adopts 7.3.12 or 7.3.13, review the applicable RPE report and MEWP manufacturer approval before use.	Visual / document review / safe function check or accepted evidence, as applicable
PO-03	Operating zone condition	Operating zone for drilling and, where applicable, powered travel: inclination below 1:10; no step or level difference exceeding 20 mm; stricter Vendor limits met. For powered travel, declared gradient and obstacle-crossing limits are compatible with the accepted route and conditions.	Visual / measurement

ID	Item	Acceptance Criteria / Requirement	Method
PO-04	Drill hole data and references	Approved drill hole data and independently traceable target references are available. Demonstrate Operator review and confirmation of the configured task and any map, route or drilling sequence, including supported operating/exclusion-zone settings, before automatic execution under 7.5.2 and 7.6.6.	Document / measurement review
PO-05	Drilling position accuracy	Completed-hole centre lies within a circular tolerance zone of 5 mm radius centred on the independently verified reference target.	Drilling and measurement test
PO-06	Hole depth, diameter and direction	Completed hole meets approved depth, diameter and direction/fixing-system requirements. No under-depth.	Drilling and measurement test
PO-07	Operating range	Required project reach and drilling orientation are demonstrated.	Function test
PO-08	Remote-controlled powered travel	For remote-controlled powered travel, demonstrate stopping on movement-control release and control-communication loss and, where 7.4.8 is adopted or required by the project, proximity warning to the Operator at the accepted configuration and Vendor-declared travel-speed and protective separation settings. Record and check stopping distance/time under A-5 and A-6, including the Vendor-declared, risk-assessed communication-loss timeout and associated safe response under 7.7.3.	Function test

ID	Item	Acceptance Criteria / Requirement	Method
PO-09	Automatic powered-travel proximity protection	For self-navigation or other automatic powered travel, demonstrate proximity detection and automatic stopping before unsafe contact or breach of the declared protective separation limits using a suitable test object at the accepted configuration and Vendor-declared travel-speed and protective separation settings. Record and check stopping distance/time under A-5.	Function test
PO-10	Depth feedback and drilling anomaly	Depth feedback and abnormal-resistance detection operate correctly. The safety response under 7.3.8 and Operator assessment and restart requirements under 7.2.6 and 7.7.3 are verified.	Function test
PO-11	Mode control, operation indicator, emergency stop and fault response	(a) Verify emergency-stop visibility, function, and visual operation indicators. (b) Test anomaly responses (7.3.8), alarms, and restart prevention across all modes using A-7. (c) Confirm a single active operating mode under 7.4.1 and a single active point of control under 7.5.2, without disabling required emergency-stop controls. (d) Verify manipulator guarding (7.7.7), including any upward-reach exceptions. (e) Safely test contact-sensing for warnings, automatic stopping, and safe-state entry; this remains mandatory even where exceptions apply.	Visual / measurement / function test / evidence review

ID	Item	Acceptance Criteria / Requirement	Method
PO-12	Dust control	During representative drilling, the source-control method is correctly positioned and effective at the drill-bit/workpiece interface, without uncontrolled visible release. Where the project adopts 7.9.10, review filtration declaration and evidence.	Function test
PO-13	Noise information	Vendor noise information/test condition reviewed. Workplace assessment arranged if required.	Document review
PO-14	Electrical, battery and IP evidence	(a) Applicable electrical, battery, environmental-protection, UN 38.3 lithium-battery transport and radio-equipment evidence matches the supplied configuration and declared ratings. (b) Claimed or project-required IP ratings have configuration-matched evidence. Verify 7.9.8 where adopted by the project. (c) Drilling tools suit the site conditions. Cables, connectors, charger, enclosures and protective devices are acceptable. (d) For in-scope site-supply or charging installations, review applicable EMSD Wiring CoP arrangements, including Code 26K, and installation evidence.	Document review / visual
PO-15	Internet capability and access control	Authorized Internet connection capability is demonstrated without bypassing safety functions. Role-based or equivalent access controls prevent unauthorized remote commands and changes to safety settings or approved drill hole data.	Function test

ID	Item	Acceptance Criteria / Requirement	Method
PO-16	BIM compatibility	Approved sample drill hole data are received or used through the Vendor-stated BIM workflow method.	Function test / data review
PO-17	Documentation and records	Required manuals, site-specific risk assessments and safe-working procedures under 7.10.1, evidence, model/mode completion certificates, confined-space certification under 7.13.5 where required, training/refresher records, competency assessments, authorization and relevant operation-history evidence, operating limits and retention arrangements are available.	Document review
PO-18	Best-practice functions	Any Best Practice function required by the project is verified. Otherwise N/A is recorded.	Function test / document review

Verification Methods

A-1 For each PO item, record the robot configuration, test conditions, result and evidence reference. Failed items shall be corrected and the affected requirement re-tested before acceptance.

A-2 The number and distribution of test holes shall be agreed before the PO check and shall cover the project drilling positions, hole sizes and operating range being accepted. A single test hole shall not be the sole basis for drilling-position acceptance.

A-3 Establish each position-accuracy reference target before drilling by a traceable method independent of the completed hole. Use the robot's normal site operating procedure. Measure the completed-hole centre at the agreed measurement surface. Each accepted test hole shall lie within a circular tolerance zone of 5 mm radius centred on the reference target.

A-4 Measure completed-hole depth by a suitable independent method and compare it with the approved drill hole data or fixing-system requirement. Under-depth is not accepted. Any permitted over-depth shall follow the

approved fixing or anchoring system or Client-approved project requirement.

A-5 Powered-travel verification:

(a) Test sensing and automatic stopping for self-navigation or other automatic powered travel, and remote-travel proximity warning where 7.4.8 is adopted or required by the project, using a suitable test object at the accepted configuration and Vendor-declared travel-speed and protective separation settings.

(b) Record the configuration, test conditions, declared sensing range/coverage where applicable, travel speed, separation distance, stopping distance/time and achieved response.

(c) Verify declared stopping limits, including applicable manual emergency-stop performance, by a safe test or suitable evidence. People shall not be used as collision targets.

(d) Check applicable ISO 3691-4 protective stopping requirements where the mobile platform is within its scope. Self-navigation performance may also be assessed under GB/T 38834.2 or ISO 18646-2.

Upward-reach guarding-exemption verification:

(e) For a claimed guarding exemption under 7.7.7, verify minimum height throughout the relevant operating range and assess foreseeable access from platforms, ladders and adjacent structures. Confirm adequate protection by distance and that all other required safeguards remain effective.

A-6 For remote-controlled powered travel, demonstrate stopping on movement-control release and control-communication loss and, where 7.4.8 is adopted or required by the project, proximity warning to the Operator using a suitable test object at the accepted travel-speed and protective separation settings. Check stopping performance under A-5 and the Vendor-declared, risk-assessed communication-loss timeout and associated safe response under 7.7.3.

A-7 Abnormality-response verification:

(a) Representative abnormality sensing and protective responses under 7.3.8 shall be verified by safe methods for all accepted operating and set-up modes, including remote-controlled operation, automatic operation and manual or local control.

(b) Record the mode, fault or abnormal condition, warning, applicable communication-loss timeout, safe response and restart prevention, including Operator review of completed and outstanding work before deliberate resumption where interrupted-task recovery under 7.5.8 is required by the project.

(c) Simulation or configuration-matched test/validation evidence may be used where inducing a real fault would be unsafe.

(d) Laboratory IP, battery-abuse and environmental-chamber tests shall not be repeated on site.

A-8 Workplace dust or noise exposure assessments required by Hong Kong law shall be performed separately from routine robot PO checks under applicable occupational-hygiene and noise-at-work requirements.

A.3 Sample Pre-use (PU) Checklist

ID	Item	Acceptance Criteria / Requirement	Method
PU-01	Robot body/platform	No visible damage, loose parts, leakage or unresolved alarm.	Visual / status check
PU-02	Drill, bit, holder and adapters	Correct tooling fitted, securely retained and not visibly damaged or excessively worn.	Visual
PU-03	Guards and covers	Guards/covers are secure and undamaged. Interlocks are functional. Drill-bit access control under 7.7.7 is effective. Verify normal status of the required robot-arm contact-sensing protective devices and other applicable collision protection under 7.7.7.	Visual / function check, as applicable
PU-04	Emergency-stop controls	Clearly visible, readily identifiable, readily accessible and functional.	Function test
PU-05	Protective sensing and abnormality status	(a) Required abnormality sensing and protective functions under 7.3.8 are ready for the intended operating or set-up mode. (b) Travel sensors under 7.4.6, and under 7.4.8 where adopted or required by the project, are clean, unobstructed and functional. Record N/A only where travel sensing is not applicable. (c) Guarding under 7.7.7 remains effective.	Visual / system check
PU-06	Depth feedback / drilling sensing	Normal status and no unresolved fault indication.	System check
PU-07	Power, battery, cables and connectors	Adequate status for intended work. No visible damage, overheating or unsafe connection.	Visual / system check

ID	Item	Acceptance Criteria / Requirement	Method
PU-08	Operator interface / remote controller	Controls, warnings, mode indication, communications, visual operation indicator and required abnormal-condition alarms operate normally.	Function test
PU-09	Dust control	Extraction/suppression equipment is connected, ready and correctly positioned to control dust at the drill-bit/workpiece interface. Required eye, respiratory and hearing protection is available and used. Where applicable, the cleaning and maintenance schedule under 7.9.1 is available and servicing due before use has been completed.	Visual / function check
PU-10	Operating zone and access route	Clear, stable and within the accepted operating-zone slope, level-difference and clearance limits under 7.3.3. For powered travel, declared gradient and obstacle-crossing limits and travel-speed/protective-separation settings match the accepted configuration and route. Fencing and access controls are checked under PU-11.	Visual
PU-11	Hazard-zone controls	(a) Operating and exclusion zones cover the full operating range and foreseeable fall zone, are fully fenced with controlled access, and have unobstructed access/egress. (b) Conspicuous signs identify the operating zone and robot operation in Traditional Chinese, English and other required worker languages. (c) Display the site layout and emergency escape route where applicable.	Visual

ID	Item	Acceptance Criteria / Requirement	Method
PU-12	Stabilizers / brakes / platforms	(a) Required stabilizers, outriggers and brakes are available and correctly set so the base remains stationary during drilling under 7.3.4. (b) For platform-supported operation, confirm secure fixation, any required stabilizing contact, the verified stable working condition and required controls under 7.3.6. (c) No worker remains on the platform during robot operation.	Visual / safe function or status check, as applicable
PU-13	Drill hole data / reference	Approved drill hole data/reference is available. Active-hole identifier/location, diameter, depth and specified direction are available to the Operator, with configured-task review and confirmation and applicable map/route/zone information before automatic execution under 7.5.2 and 7.6.6.	Document / system check

Annex B: Standard Workflow for Deployment and Maintenance

Stage	Action
1. Project requirements	(a) The Client defines and approves project drill hole data, work scope and acceptance values and confirms robot suitability and deployment arrangements before procurement (7.1.3). (b) The Purchaser provides the site-specific risk assessment and safe-working procedure before delivery of the robot to site (7.10.1).
2. Product submission	The Vendor provides robot capability, operating limits, model-specific manuals, conformity/test evidence and intended operating arrangements.
3. Pre-delivery inspection	(a) The Vendor checks the robot configuration, safety functions and supply documents under 7.10.2. (b) Purchaser confirms delivery access, transport, site services and personnel qualifications using Annex A.1.
4. Site preparation	The Purchaser confirms readiness and personnel briefing under 7.10.3, including fenced operating/exclusion zones, controlled access/signage, power and charging, dust/noise controls, target references, any platform/fall-zone controls and site conditions meeting declared environmental limits.
5. Pre-operation inspection	(a) The Operator, with Vendor support, performs Annex A.2 checks and demonstrations under 7.10.4, including operating modes, abnormality responses and applicable proximity responses, emergency stops, drilling accuracy and required collision/contact protection. Where specialist checks or measurements are needed, they shall be performed by persons competent for the relevant work. (b) The Purchaser arranges site checks. (c) The Client accepts PO results after failed requirements are corrected and re-tested.

Stage	Action
6. Pre-use inspection	The Operator checks the robot, guarding, required arm contact-sensing devices and other applicable collision protection, work area, PPE, alarms, drilling references and any MEWP controls before each shift or use and after relevant changes under 7.10.5 and Annex A.3. Failed items are corrected and affected functions re-tested before use.
7. Routine operation	(a) The Operator continuously supervises authorized drilling and travel, works within declared limits and stops hazardous operation where required. (b) The Purchaser maintains fencing and controlled access. (c) The Operator restarts only deliberately after safe conditions are restored.
8. Maintenance, removal and records	The Purchaser arranges: (a) Maintenance and inspections under 7.10.6 to 7.10.8, with competent personnel and Vendor instructions. The Operator re-verifies affected functions before return to service. (b) Dismantling and removal under 7.10.1. (c) Retention of required records under 7.11.4 to 7.11.7. Backup/recovery under 7.11.9 is included where adopted by the project.