Responsibilities of Engineering Surveyors under ISO 9000 in Hong Kong Construction Industry

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Abstract

This paper introduces the ISO 9000 standard and discusses the responsibilities of engineering surveyors under ISO 9000 Certification in Hong Kong construction industry.

1. Introduction

It is well understood nowadays that that quality control is the most critical issue for any engineering project, including construction project. If there were a quality problem, serious loss in economy and human lives might be caused. As a consequence, quality issue has become a part of engineering surveyors' daily lives. The ISO 9000 has also become a standard of quality management for the construction industry. In this paper, a discussion of ISO 9000 in Hong Kong Construction Industry will be presented.

2. The ISO 9000

ISO (International Organization for Standardization) is an agency which was founded in the mid 1940s in Switzerland, whose main objective is to promote the development of international standards and related activities to facilitate global exchange of commodities and services.

ISO 9000 is a series of Quality System Standards. It is not the purpose of the ISO 9000 to concern with the quality of a particular product or service, but to state the requirement of a quality system by which an organization is able to deliver consistently a product or service required by its customers. Thus, the Standards can be applied to all types of trade, industry or organization. Today, more than 90 countries have adopted the ISO 9000 Standards as equivalent to their national standards, and the Standards have gained increasing international recognition as a benchmark for quality assurance.

ISO 9000 Standards and their principal elements are given in Figure 1 and Figure 2 respectively. In Hong Kong, most of the construction firms are certified to the ISO 9002 Standard. Implementation of ISO 9000 in a construction company is given schematically in Figure 3. Guideline for certification of the quality system of a company is given in "Certification Principles & Practices" published by ISO. Certification process is usually carried out independently by third party Registrars whose quality audit operations are accredited by ISO.

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Figure 1 ISO 9000 Standards.

CONTROL Elements	DESCRIPTION	ISO 9001	ISO 9002	ISO 9003
1	Management responsibility	√	√	√
2	Quality system	√	√	√
3	Contract review	√	√	
4	Design control	√		
5	Document control	√	√	√
6	Purchasing	√	√	
7	Purchaser supplied product	√	√	
8	Product identification & traceability	√	√	√
9	Process control	√	√	
10	Inspection & testing	√	√	√
11	Control of inspection, measuring & test equipment	√	√	√
12	Inspection & test status	√	√	√
13	Control of non-conforming product	√	√	√
14	Corrective action & preventive measure	√	√	
15	Handling, storage, packaging, preservation & delivery	√	√	√
16	Quality records	√	√	√
17	Internal quality audits	√	√	
18	Training	√	√	√
19	Servicing	√	√	
20	Use of statistical methods	√	√	√

Figure 2 Quality control elements of ISO 9000 Standards.

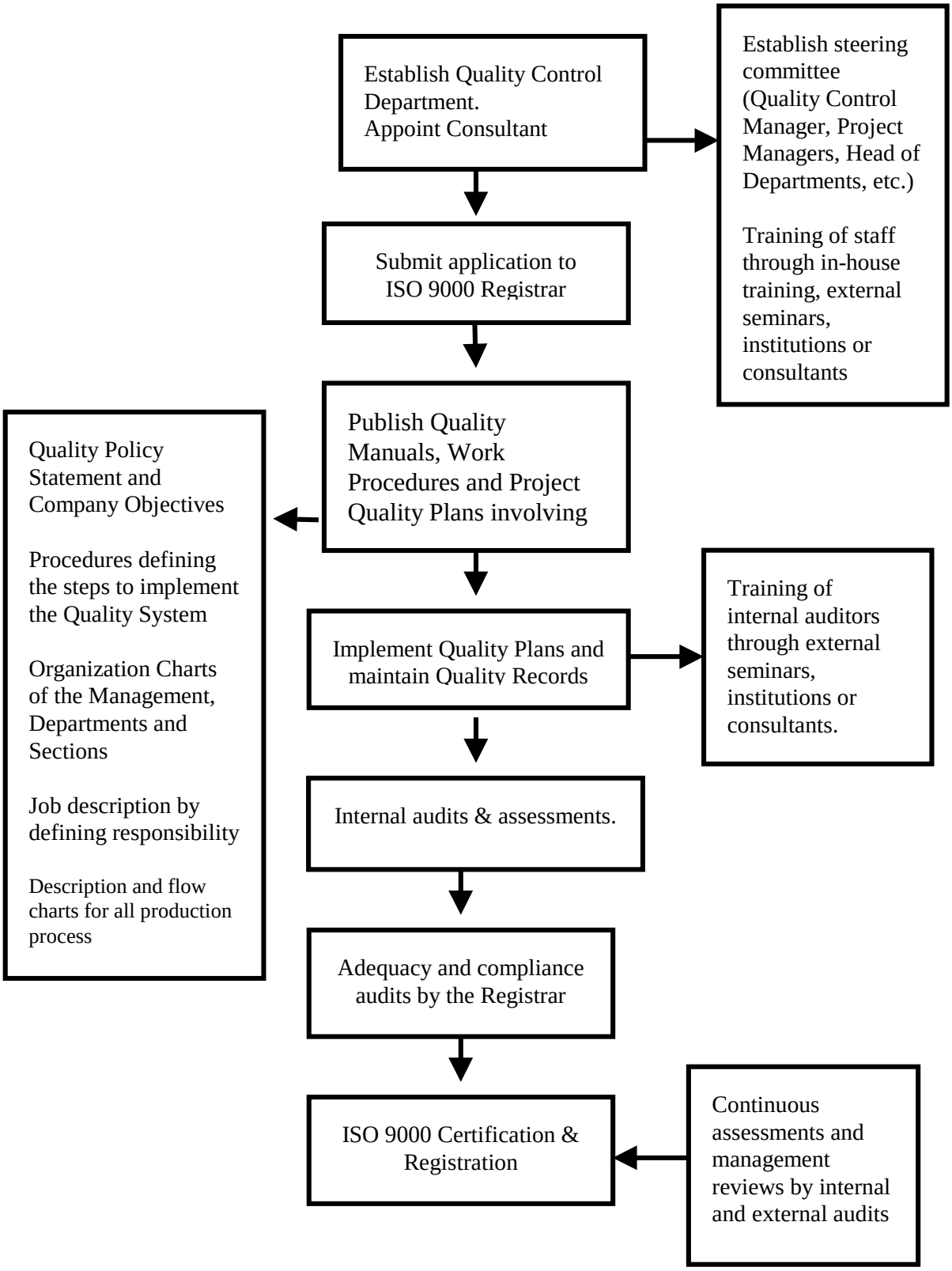

Figure 3 Implementation of ISO 9000 in a construction or survey firm.

3. Benefits of ISO 9000 Certification

By experience, noticeable results in customer satisfaction and cost savings are reported after implementing ISO standards. The quality management system has helped construction and surveying companies to focus on their goals and operations. Under the standards, good relationship between contractors and clients is established by having well-defined and mutually agreed requirements for the product and service. Based on documented procedure and instruction of the quality system, every worker has a clear understanding of one's duty. Cautious and preventive attitude will be developed throughout the organization. More innovative and efficient technology will be adopted by the quality system to reduce cost of materials, labor wages and time for the production. Thus, the system will result in better quality of works, more efficient allocation of resources, less wastage of materials, and, the most important of all, better site safety.

Companies that have been certified under ISO 9000 standards would likely require their suppliers to have ISO 9000 quality assurance systems for their products. Therefore, suppliers which have achieved ISO 9000 certification will automatically conform to the requirements of such purchasers. Besides, purchasing departments of companies usually check with the Registrar's Directory of ISO Certified Firms when selecting suppliers of products and/ or services.

Construction companies wishing to do business with government agencies will recognize the certification as a competitive advantage. For examples, only ISO 9000 certified construction firms are allowed to tender government housing projects in Hong Kong and Singapore. In the following sections, we shall discus the responsibilities of engineering surveyors under some of the control elements of ISO 9000 in the construction industry of Hong Kong.

4. Quality System

One of the responsibilities of an engineering surveyor is to carry out surveys according to the quality system. The main principle of a quality system is to satisfy stated or implied needs of customer(s) in a construction project. For security reason in running a business, a quality system and procedures for implementation are described in five levels of its quality control documents. They are:

1. Level 1 – Quality Manuals for board of directors and top management
2. Level 2 – Quality Procedure Manual for project directors and managers
3. Level 3 – Department/ Section Manuals for managers and supervisors
4. Level 4 – Operation/ Work Instruction for supervisors, technical staffs and clerical staffs
5. Level 5 – Quality Records

In the construction industry, different projects may have different contract requirements and customer expectation. Therefore, Project Quality Plans (PQP) and Survey Quality Plan (SQP) may be required as supplement to the company's quality system. PQP and SQP must be integrated with related quality plans of the quality system. A SQP, which is designed for a large construction project, usually has the following documents:

1. Job description and responsibilities of all survey personnel (chief Surveyor, senior Surveyor, surveyor, survey assistant, etc.) in the project together with a Survey Organization Chart.
2. Method Statement for integrating SQP with related quality plans.
3. Method statements for establishing, maintaining and recording survey data.
4. Survey Inspection Plan.
5. Method statements for surveying different structures of the construction.

6. Survey Specifications and Allowable Tolerances.
7. ITP(Inspection and Testing Plan) for geodetic control, setting-out, as-built, monitoring and detail surveys.
8. ITP for testing and calibration of survey instrument.
9. WI (Work Instruction) for methods and procedures of testing and calibration of survey instruments.

Modules of surveying operations and the database of a SQP are given in Figure 4.

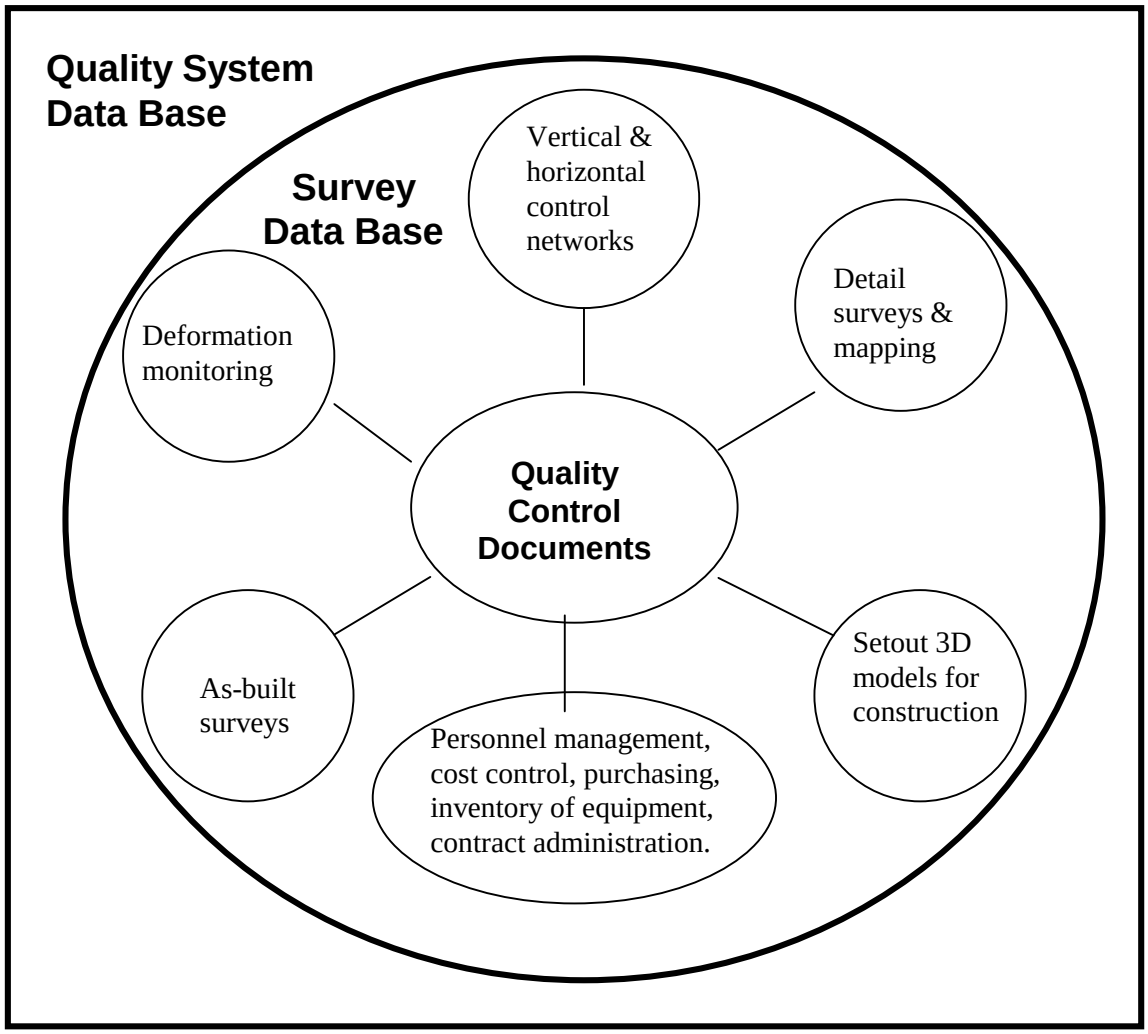

Figure 4. Modules of surveying operations and database inside a Survey Quality Plan.

5. Management Responsibility

The Standards describe quality policy, organization of project team, responsibility and authority of all personnel, and resource allocation. Thus, in a construction project, it is the responsibility of an engineering surveyor to perform:

1. Establishment of vertical and horizontal control points on site.
2. Setting-out of structural elements and formwork for construction.

3. Monitoring of settlement and deformation of existing structures for the safety of the public.
4. Preparation of detail plans and as-built drawings for design and dimensional control of the product.
5. Liaison with clients (developer, consultants, engineers or the public) for any setting-out discrepancies or boundary disputes.
6. Checking and calibration of surveying instruments.
7. Training of junior surveyors and assistants.
8. Proper personnel management and administration of the project.

6. Contract Review

The objective of contract review is to ensure all contractual requirements of a project at pre-tender and post-tender phases can be fulfilled. The common error of "Contract Review" in the construction and surveying industries is that review is often made after signing of a contract. ISO 9000 Standards state that a review should take place before a tender document or contract is accepted. All verbal agreements which constitute the contract should be included in written documents for contract review. If the review is made after the signing of a contract and found that the requirements of the contract differ substantially from conditions laid down in the tender documents or quotations, the company may not be able to complete the project technically, financially and on time.

Therefore, it is the responsibility of the Chief Surveyor to evaluate and select survey staffs, suppliers of survey materials and equipment, and survey sub-contractors to fulfill each individual project. Special attention shall be made to foreseen their technical capabilities and resources to execute the proposed work within the time frame and survey budget of the project.

7. Document Control

Under the ISO 9000 standards, it is required that the procedures and performance of quality practices must be recorded in traceable records, and that the quality records must be retrievable easily to meet particular demand or purpose. Thus, it is the responsibility of a surveyor to ensure that all survey documents and data of a project are properly identified, labeled and addressed in files or computer systems so that wrong use and loss of important data can be avoided.

Use of computer system, relational data-base management, MISC(Management Information System for Construction) and E-mail communication networks are recommended to address these documents. Many relational database which are available in the software market provide user query languages to make it easier to work with the database, to build integrated applications from multiple files, to analyze records and customize outputs.

8. Process Control

Under ISO 9000 Standards, all construction processes must be carried out under controlled conditions. Controlled conditions comprises:

1. Approved method statement for the construction process including surveying.
2. Use of suitable material and equipment.
3. Safe working environment.
4. Compliance with the reference standards, building codes and project quality plan.

5. Monitoring and control of construction stages and building materials characteristics in accordance with ITPs for surveying and construction.

During site formation and construction of structural elements, the surveyor is responsible for accurate setting-out of their alignments and positions on-site. Setting-out is allowed to proceed only when construction drawings with sufficient information have been finalized and approved by the Architect or the Engineer. The surveyor should ensure latest and sufficient setting-out data are received. He/ she should check alignments and clearance of the new structures from property lines, electric cables, roads or other adjoining structures according to Town Planning Regulations or other design criteria. He/ she should check main dimensions and reconcile them by adding intermediate dimensions given in the drawings.

Working “from whole to part”, control points should be established on undisturbed and permanent features such as walls, concrete foundations, curb line, etc. Network of closed traverses which start from and close onto different known control points is recommended as accuracy of the survey result can be evaluated and refined by using adjustment methods in computation. Surveyors should refer accuracy standards, specifications and guidelines published by local government for vertical and horizontal control surveys for construction projects.

Method of setting-out will be designed by surveyors choosing suitable instrument, personnel, operational model and data processing method. Other details such as the function, type, size and location of the structure are also considered. For example, in the case of setting-out very high structures, adjustment of survey measurements may be required to allow for the Earth’s curvature. It is particularly important that surveyors involved in setting-out should have an understanding of instrumental accuracy and the theory of errors so that the required accuracy can be achieved with less time and less expensive instrumentation.

Acceptance criteria and allowable tolerances for setting-out in building construction can be found in ISO3443, ISO 7976 and ISO 7737. These standards are applicable in both building construction and civil engineering. Depending on the requirements of the setting-out, higher accuracy may be required. Depending on the time allowed for setting-out, the Surveyor should carry-out independent check of the setting-out points, lines or levels by one or more of the following methods:

1. Measurement from different control points.
2. Using different survey method.
3. Using different survey instrument for measurement.
4. Checking by a different survey team.
5. Checking the result against previous survey records, if they are relevant with each other.

Squareness of building formwork should be checked by measuring against known diagonals and dimensions before placing concrete or final positioning. Profile boards for building works must be erected far enough away so that they would not be disturbed. Setting-out and measurement methods can also be found in ISO 4463.

Site conditions should be investigated to find out if there is a history of ground movement due to the effects of water, existing stability of slopes, mining activity or existing fault lines. Monitoring of movements of any land or structures by surveying techniques will be made by reference to permanent control points outside the area of known influences. Both traditional and photogrammetric methods should be considered to achieve cost-effectiveness in

deformation monitoring surveys. Monitoring should continue during construction or after the product is in use. This kind of survey is important for the sake of public safety as well as the safety of construction workers on site.

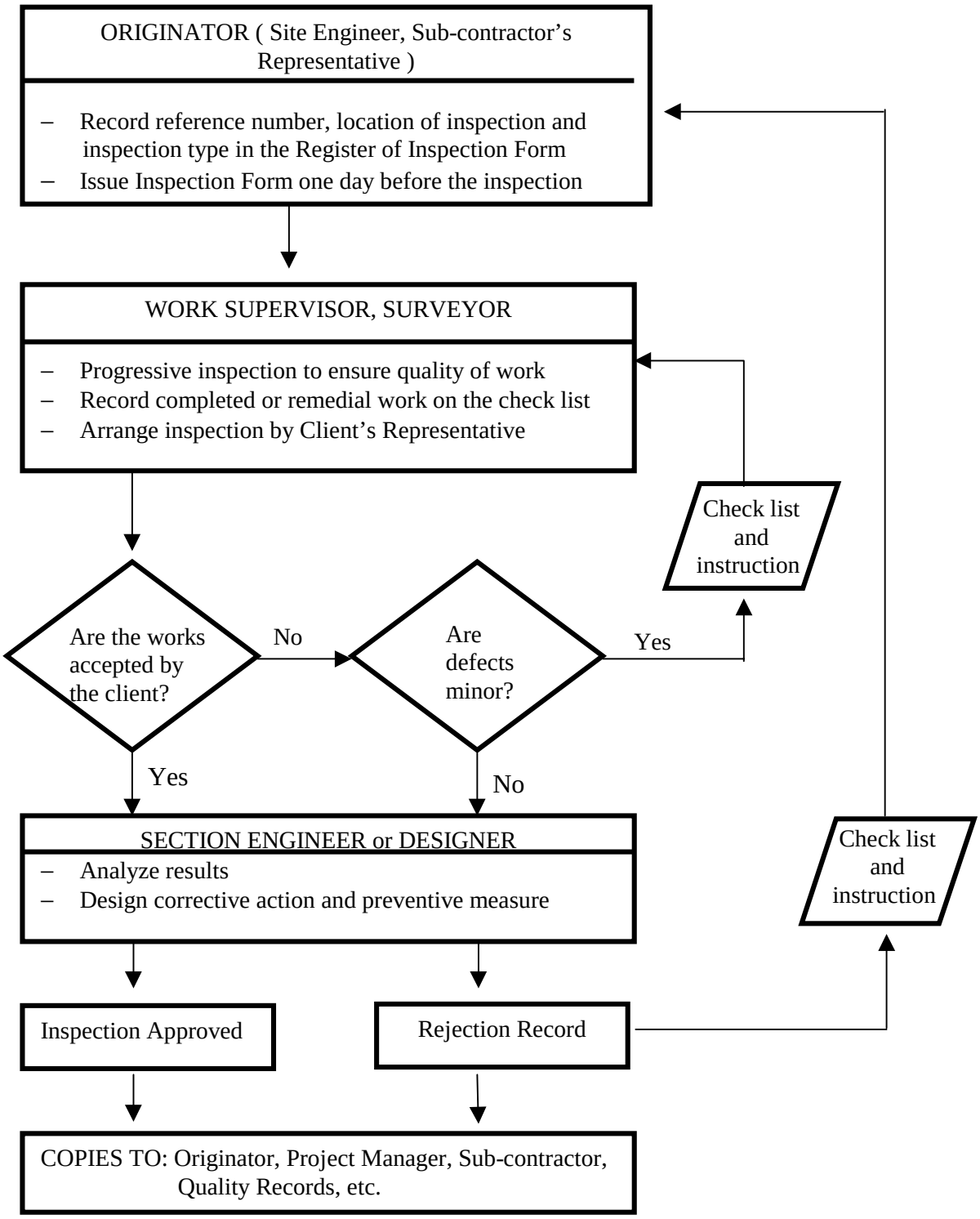

Figure 5 Flow chart for site inspection of works in construction.

9. Inspection and Testing of Works and Materials

ISO Standard describes how materials and works should be inspected and tested throughout the project. The Material Controller is responsible for the inspection and verification of incoming materials on site. The surveyor will assist the Material Controller so that the quality of survey materials and instruments are properly inspected for any defects. Any non-conformance should be reported immediately to the Purchasing Officer, Site Quality Assurance Engineer and the Project Manager.

During the project, Project Manager and site staffs are responsible for ensuring that inspection of works are carried out according to management procedures, approved Method Statements, ITPs, Work Instructions and other procedure manuals. Flow chart for site inspection of works during construction is given in Figure 5.

10. Inspection, Measuring and Test Equipment

The Standard specifies that all measuring and test equipment, whether owned by the company, on rental or provided by the customers, must be controlled, calibrated and maintained. This is to ensure that all measurements are consistent with the accuracy and precision required of the job. Test certificates and calibration of survey instruments and other inspection equipment must be traceable to national or international standards, and in accordance with documented procedures. Documented procedures are:

1. ITP for testing and calibration of survey instrument.
2. WI(Work Instruction) for methods and procedures of testing and calibration of survey instruments. Methods and procedures for checking ordinary survey instruments can be found in ISO 8322.
3. Schedules and records of calibration.

Records of calibration and check result must be maintained on schedule. Sub-contractors' instrumentation should comply with the same procedure or have a similar procedure giving the same degree of control and approved by the Project Manager.

One common error of applying " Control of Inspection, Measuring and Test Equipment " in construction is that computer softwares are usually not properly inspected. There are numerous cases in tunnel surveying in which computer softwares being used are not compatible with the laser-guided shield or drilling machines. This would cause misalignment of the drilling machines and incur a lot of overbreaks or underbreaks at an expanded expense of the company. Therefore, before the softwares are being used in production, they should be checked for indication of their acceptability to products during the verification, installation and service process. Thereafter, the inspection should be carried out at regular intervals in order to maintain the Quality System. Another common error is that the reference inspection, measuring and testing equipment of production facilities have not been verified by international or national approved standards. Other common errors include the lack of display of calibration status or an approved identification record.

11. Control of Non-conformance and Corrective Action

Any non-conformance which does not fulfill contractual requirement should be identified and reported to the Quality Control Manager and the Project Manager. Department heads should record all incidents of failure and segregate any item or area of work at fault in order to enable other work to proceed with minimum interruptions. All non-conforming materials and workmanship shall be reviewed by authorized personnel in accordance with documented

procedures so that decision can be made to carry-out corrective action and to prevent recurrence.

The following alternatives are usually considered for corrective action:
1. Rework to meet specified requirement. In this case, remedial work is required.
2. Revise the design and adopt existing product. For example, realignment of a railway tunnel to suit existing concrete liners of a 900 meter section which is out of tolerance.
3. Accept under concession from the client.
4. Reject and be replaced by a new product.

12. Quality Records

As discussed in the section of document control, quality records must be retrievable easily to meet particular demand or purpose. In order to facilitate surveying operations, quality records are usually categorized into project documents, construction drawings, management documents, reference documents, and communication documents.

Project documents are required for proper organization and management of an individual project. They comprise:
1. Project Quality Plan, Survey Quality Plan, Work Procedure Manuals and other management procedure manuals;
2. Contract document including records of tenders, contracts and agreements with
3. ITP and Method Statements for construction; inspection and test records, defect reports, audit reports, management review reports and training programs;
4. Certificates of Completion and records of payment, cost-control records, construction schedules and progress reports, variation order and claims;
5. ITP and Method Statements for surveys which describe field observation procedure, data collection methods, instruments to be used, computation models and output format;
6. ITP for testing and calibration of survey instruments; etc.

Construction drawings are regarded as contract document in construction projects, and comprise:
1. A Drawing Register;
2. Drawings, in paper or digital formats, of construction design, control network, setting-out, as-built surveys, check records, deformation monitoring, topographical survey including utility services above and below ground, and quantity surveying;
3. Setting-out information, instructions and sketches from the Engineer or the client's representative;
4. Plans of site boundary and cadastral surveys; etc.

Management documents comprise documents pertaining to the day to day operation and management of the survey teams for the project. They are:

1. Information of survey personnel;
2. Cost control and survey budgets;
3. Horizontal Control points, level bench marks, calibration base-net and coordinate systems;
4. Records of survey inspection, field books, survey request forms and daily report;
5. Inventory of survey equipment, software and materials;
6. Purchase requisition, purchase orders, delivery notes and transfer notes;
7. Certificates and calibration record of survey instruments; etc.

Reference documents are used in the design and decision-making process such as:
1. Standards, statutes, regulations and relevant publications of government departments;
2. Specifications, allowable tolerances and acceptance criteria for the construction;
3. Survey consultants and subcontractors;
4. Supplier of survey materials and equipment;
5. Manufacturers' and suppliers' documents including operating manuals, catalogues, products' specifications and price lists, etc.

Communication documents are correspondence, faxed documents, minutes of meetings, internal memos, e-mails, etc.

13. Quality Audits

A quality system is maintained by internal quality audits, management reviews and feedbacks from quality training programs. In surveying operations, practices will be reviewed by the chief surveyor or the quality controller of the project at regular intervals. The audit will evaluate selected survey jobs according to the following guidelines:
1. Suitability of data and documents for the intended purpose.
2. Adherence to instructions, method statements, specifications and standards.
3. Proper application of surveying methods and procedures.
4. Completeness, correctness and clarity of field notes, measurements, computations, plans and other survey documents.

Any deficiencies found by the audit are recorded and brought to the person who is responsible for the problem and carried out corrective action with preventive measure for future operations.

14. Training

ISO 9000 Standards specify that procedures must be established and maintained to identify the training needs of all personnel performing duties that affect quality. Awareness training on the quality system should be given to every new employee to reduce the time of understanding the requirements of his/ her job. Records of training must be kept and maintained.

Safety Training is mandatory to all levels of surveyors working in construction sites. Training of surveyors to use precise and modern instruments is necessary in order to keep pace with rapid advancement of surveying technology we are experiencing. In order to achieve the same level of quality, more attention and training should be given to surveyors from overseas because surveyors from different countries may have adopted different standards of surveying practice.

15. Conclusion

We have presented the responsibilities engineering of surveyors under ISO 9000 certification in Hong Kong construction industry. By experience, we always emphasize quality management during the early stages of a construction project because the ability to influence the quality, cost and schedule of the project can best be achieved at that time.

A well-structured quality management system furnishes technicians, supervisors and managers with details on surveying and construction methods; wages and labor for production; selecting equipment and materials; assigning production costs; acquiring

specialty subcontractors and consultants; and assigning duties to each individual of the construction team. As an integral part of the construction business, a quality system helps reduce costs, increase output, improve site safety, secure markets, and totally satisfy its customers.

The adoption of ISO 9000 standards in surveying, construction and other industrial sectors will continue to grow. Whoever is able to supply better quality products at lower cost will capture more global market share. And quality system is the only tool in pursuit of such excellence and profitability.

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