



Quality Control of Construction Projects

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Ying Cao

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Cao Ying

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Academic Supervisor

Heikki Salkinoja

Company Supervisor

Zhang Yuling

Company

Third Chemical Engineering

Abstract

The purpose of this thesis was to find out the shortcoming of quality management in construction projects of Third Chemical Engineering Construction Co. Ltd. (TCC), to help them strengthen the quality management system, and raise the overall level of quality management. The goal was to improve the quality of product, work, and service, so that the enterprise can win in the market competition.

The research was carried out in Jiangxi project company of TCC, which locates in Jiangxi Province in China. During a 4-month internship, the theoretical data about quality management system of the company was learnt, and the work experience on the construction site was required.

Both the method in application of the company and the methods consulted from Internet were researched and applied. The actual conditions being combined, and the quality standard of ISO 9001:2008 being used, a systematic analysis and summary were made for the quality management of construction for the company.

Through the thesis, the function and importance of quality control was learnt. Besides, some suggestions for the quality management and control of construction project were given and have been accepted by company supervisor of TCC, to improve their quality management.

Keywords

quality control, quality management system, construction process

Confidentiality

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1 Introduction

As the market economy has developed, market competition has had an important role of the law of survival of the fittest in every corner. The pressure of construction enterprises from the market and competitors will be greater and greater, as well as the increasing requirements of customers of quality assurance, which require the construction companies to improve their internal quality, strengthen management, in particular, pay close attention to quality control.

Quality is the symbol of human civilization, and with the progress of human civilization, quality control will play an incomparable role in the business. It can be said that if there is no quality control, there is no economic benefit. Construction projects are an extremely complex process, involving a wide range. There are plenty of factors affecting the quality of construction, such as design, materials, machinery, topography, geology, hydrology, meteorology, construction technology, methods of operation, technical measures, management systems, and so on. Because of the fixed project location, large volume and different location of different projects, the poor control of these factors may produce quality problems. During controlling the whole process of construction, only accord with the required quality standards and user promising requirements, fulfilling quality, time, cost, etc., construction companies could get the best economic effects. Construction companies must adhere to the principle of quality first, and insist on quality standards, with the core of artificial control and prevention, to provide more high quality, safe, suitable, and economic composite products. (Examda)

From May 3 to August 31, 2009, the writer of this thesis was working in The Third Chemical Engineering Construction Co. Ltd. (TCC) as a quality control engineer. TCC is large-scale business of construction and installation of Chinese petrochemical industry. This thesis was based on the research in quality management system, combining with the

company's status and the analysis of existing problem, during the internship in TCC.

In the thesis, general methods including both the method applied by the company and the methods consulted from Internet are researched and applied. Through these methods, the actual conditions being combined, a systematic analysis and summary is made for the quality management of construction for TCC. The quality standard of ISO 9001:2008 will be used in building up the quality process for the company operation.

This thesis elaborates the quality control of construction projects in TCC. The first chapter introduces the overview of TCC, presenting the business type and scope. The next chapter of quality management provides the theoretical background. The chapter of quality control on TCC illustrates the research process and results. The summary and evaluation is given in the conclusion chapter.

2 Third Chemical Engineering Construction Co. Ltd. (TCC)

2.1 General introduction

The Third Chemical Engineering Construction Company of China was founded in 1962, and restructured into The Third Chemical Engineering Construction Co. Ltd. (TCC) in September, 2008. It belongs to China Chemical Engineering Co. Ltd., and it is a traditional state-owned construction enterprise with more than 40 years history. The headquarter of the company locates in Quanshan district of Huainan City, Anhui Province, China. And its branches or project companies are in more than 20 provinces of China, such as Liaoning Province, Qinghai Province, Shandong Province, Jiangxi Province, Yunnan Province, Sichuan Province, Hainan Province, Fujian Province, etc. It has total 7000 employees and about 2000 temporary workers.

Since its founding, TCC has built and delivered over 800 projects of various large and medium sized plants and facilities across China in the fields of chemical fertilizer, chemical, petrochemical, fine chemical, metallurgical, energy, light industry & textile, foodstuff, pharmaceutical, environment protection, bridges, architectural building construction, urban development and decoration works etc.



Figure 1. Achievements in various fields of engineering projects (Sinotcc.com)

2.2 Enterprise's qualification

TCC possesses Grade I qualification for a number of chemicals such as petroleum engineering construction Prime contract, and the qualification for design, supervision, and engineering consultation. In 1996, the company acquired American Society of Mechanical Engineers ASME standard "U" logo license certificate. It owns professional qualification certificate of boiler installation, maintenance, alteration, design of Category1 and Category2 pressure vessel, plant and on-side welding of all kinds of pressure vessels manufacturing, all kinds of pipe-fitting, non-destructive testing and so on. Besides, it owns China Construction Social Credit AAA Level Qualification (The main qualification certificate of TCC is attached on Appendix 1).

2.3 Main business of TCC

The main business includes contracting or sub-contracting of construction and installation engineering, design and management of engineering, complete order, transportation and keeping, quality inspection, personnel training, technical consultation, monomer and linkage testing, maintenance, overhaul and reform. In the aspects of construction and installation, the main items include pile and foundation treatment, earthwork and slope protection, construction and decoration, industrial and civil precast production, design and manufacture of pressure vessels and equipment, fittings, fasteners and finishing of pipe, welding of ferrous and non-ferrous metals with non-metallic pipe, long-distance pipeline welding and pipe through the roof, equipment, lifting and transportation, mechanical equipment installation, large storage tank construction, spherical tank welding and the overall heat treatment, large-scale steel structure fabrication and installation, water supply and drainage, heating, ventilation, corrosion protection of pipeline of construction and equipment, thermal insulation and cold insulation, transmission and distribution of electric and installation and commissioning of the electrical system, automatic installation, testing and welding training of control system, physical and chemical testing, as well as chemical and physical cleaning.

3 Quality management

China National Standard GB/T19000: 2000 has defined quality management as the activities of coordination of command and control about the quality. From the definition of quality management, it is the sum of all management activities, including planning, organization, implementation, inspection, monitoring, auditing and others, in order that the quality of product can satisfy the updating quality requirements. (Baidu Library)

3.1 The project management process

A project management process is the management process of planning and controlling the performance or execution of a project. Traditionally, project management includes a number of elements: four to five process groups, and a control system. Regardless of the methodology or terminology used, the same basic project management processes will be used.

Major process groups generally include (Wikipedia):

- Initiation
- Planning or development
- Production or execution
- Monitoring and controlling
- Closing

Large scale development requires both a technical process and a management process. The technical process is a product-oriented process. It defines the activities and methods for creating the product. It includes a life cycle model and methods for performing the activities of each phase. The management process is a project-oriented process. It defines the activities and methods for planning the work, organizing and motivating those who will do

the work, and tracking progress to insure the project is completed on time within budget and at an acceptable level of quality. In practice it's difficult to separate one process from the other. Their activities overlap and interact throughout the project as shown in Figure 2. During a project the technical process and management process tend to amalgamate into one project process.

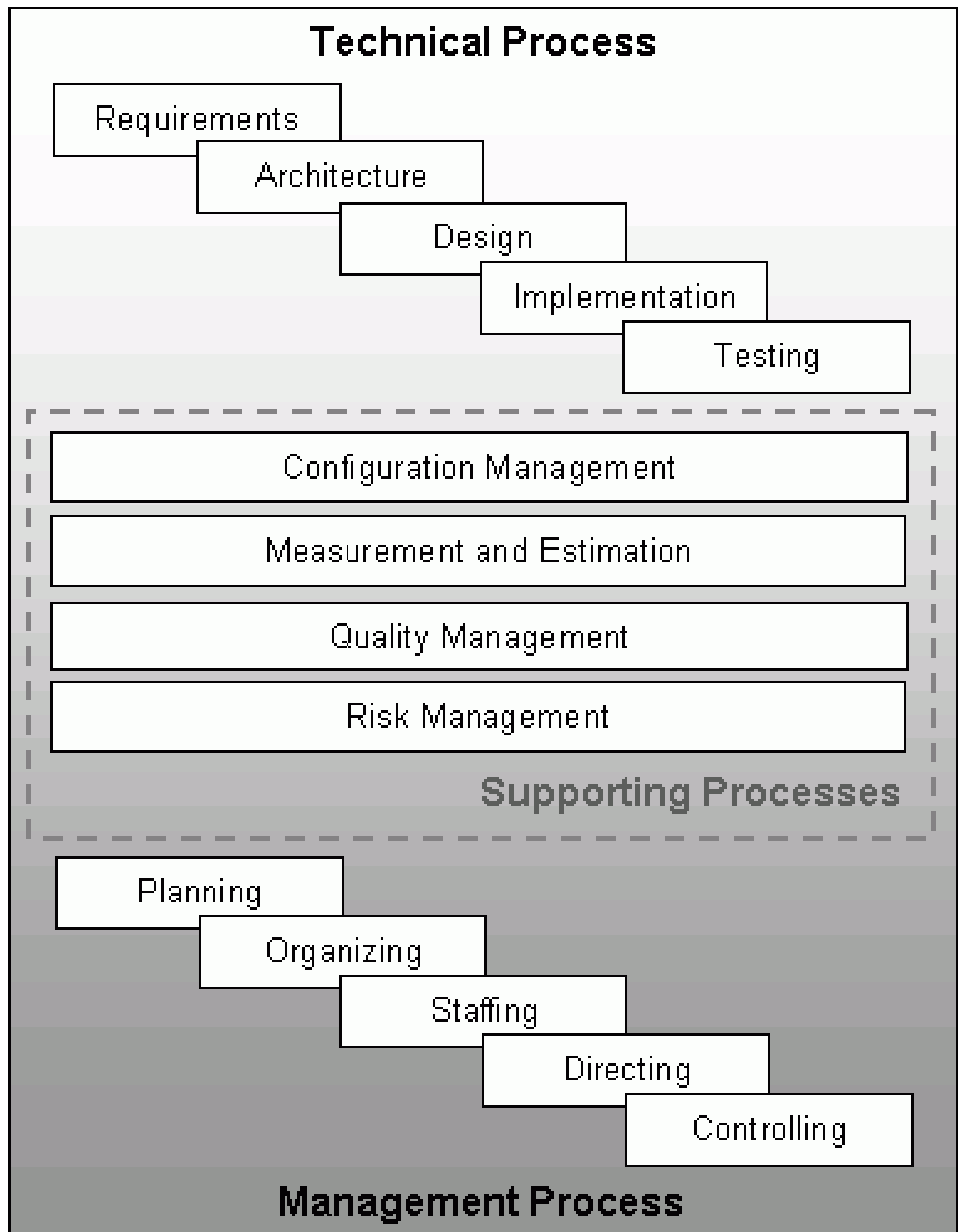


Figure 2. Technical process and management process (StaffTechs)

3.2 Quality management standard

ISO

"ISO (International Organization for Standardization) is the world's largest developer and publisher of International Standards. ISO is a non-governmental organization that forms a bridge between the public and private sectors. On the one hand, many of its member institutes are part of the governmental structure of their countries, or are mandated by their government. On the other hand, other members have their roots uniquely in the private sector, having been set up by national partnerships of industry associations. Therefore, ISO enables a consensus to be reached on solutions that meet both the requirements of business and the broader needs of society. "(International Organization for Standardization (a))

ISO9001

ISO9001 is an internationally recognized standard for the quality management. ISO9001 standard applies to the processes that create and control the products and services an organization supplies. It prescribes systematic control of activities to ensure that the needs and expectations of customers are met. It is designed and intended to apply to virtually any product or service, made by any process anywhere in the world. ISO 9001 is one of the standards in the ISO 9000 family. (ISOQAR)

The ISO 9000 family of standards represents an international consensus on good quality management practices. It consists of standards and guidelines relating to quality management systems and related supporting standards. The term ISO 9000 refers to a set of quality management standards. ISO 9000 currently includes three quality standards: ISO 9000:2000, ISO 9001:2000, and ISO 9004:2000. ISO 9001:2000 presents requirements while ISO 9000:2000 and ISO 9004:2000 present guidelines. (SUINSYS Management Consultant)

ISO 9001:2000 (the transition to ISO 9001:2008 is now taking place) which gives the requirements for quality management systems is now firmly established as the globally

implemented standard for providing assurance about the ability to satisfy quality requirements and to enhance customer satisfaction in supplier-customer relationships. (International Organization for Standardization (b))

Implementing a Quality Management System will motivate staff by defining their key roles and responsibilities. Cost savings can be made through improved efficiency and productivity, as product or service deficiencies will be highlighted. From this, improvements can be developed, resulting in less waste, inappropriate or rejected work and fewer complaints. Customers will notice that orders are met consistently, on time and to the correct specification. This can open up the market place to increased opportunities. (ISOQAR)

ISO 9001:2008

ISO 9001:2008 is the standard that provides a set of standardized requirements for a quality management system, regardless of what the user organization does, its size, or whether it is in the private, or public sector. It is the only standard in the family against which organizations can be certified – although certification is not a compulsory requirement of the standard.

Without satisfied customers, an organization is in peril. To keep customers satisfied, the organization needs to meet their requirements. The ISO 9001:2008 standard provides a tried and tested framework for taking a systematic approach to managing the organization's processes so that they consistently turn out product that satisfies customers' expectations. (International Organization for Standardization (c))

Quality management systems - Requirements

The organization shall establish the standards of quality management system, and form it to document, implementing and maintaining it, and continually improving its effectiveness.

Organizations should:

- identify the processes needed for Quality Management System and its application in the organization.
- determine the sequence and interaction of these processes.

- determine the necessary criteria and methods to ensure the effective operation and control of these processes.
- ensure the availability of necessary resources and information to support the operation and monitoring of these processes.
- monitor, measure and analyze these processes
- implement necessary measures to achieve the planned results and continuous improvement of these processes.

Organizations should manage these processes according to the standard. (Baidu baike)

4 Quality control of TCC

Quality control is a process employed to ensure a certain level of quality in a product or service. It may include whatever actions a business deems necessary to provide for the control and verification of certain characteristics of a product or service. The basic goal of quality control is to ensure that the products, services, or processes provided meet specific requirements and are dependable, satisfactory, and fiscally sound.

Essentially, quality control involves the examination of a product, service, or process for certain minimum levels of quality. The goal of a quality control team is to identify products or services that do not meet a company's specified standards of quality. If a problem is identified, the job of a quality control team or professional may involve stopping production temporarily. Depending on the particular service or product, as well as the type of problem identified, production or implementation may not cease entirely. (wiseGeek).

4.1 Construction quality control of production factors

4.1.1 Human control

As the main activity part of production process, the overall quality and individual ability of human will determine the results of all quality activities. So, human are considered as both the controlled targets and controlling motivation of other quality activities. (Cheng Hu)

The contents of human control includes the overall quality of organization and individual's knowledge, ability, physical condition, psychological state, quality consciousness, behavior, concept of organizational discipline, and professional ethics.

The main measures and approach of human control on construction sites in TCC are summarized as follows.

- (1) The management objectives and responsibilities of project manager being considered as the center, the organization of project management should be set up reasonably with appropriate management personnel.
- (2) With the strict qualification review of sub-units, the overall quality of sub-units should be controlled, including the technical quality, management quality, service and social reputation. To prevent the qualification out of control, the sub-contract operations should be forbidden.
- (3) The operating workers should be asked certificates, particularly important technical trades, special trades, and aloft work, etc.
- (4) The training, discussions and exchange activities of quality assurance should be carried out, to strengthen staff's quality consciousness.
- (5) There should be very strict on-site management system and production discipline, and the standard of operation technology and management activities.
- (6) Incentives and communication activities should be promoted to arouse staff's enthusiasm.

4.1.2 Materials control

Materials (including raw materials, finished products, semi-finished products, components and parts) are material conditions of construction, and material quality is one of necessary conditions to ensure construction quality. (Cheng Hu)

Main contents of quality control of materials:

(1) Material procurement

The contractor should purchase materials based on the integrated consideration of engineering characteristics, construction contracts, and the scope of application, construction requirements, the performance and price of materials. The procurement should be arranged in advance according to the construction schedule. Project manager department or enterprises should establish common information of material suppliers and track the market timely. If necessary, material sample or field trip is required, and the strict instruction of quality items in material procurement contracts should be paid attention.

(2) Material testing

Through a series of detection methods, the material data obtained is compared with quality standards, to judge the reliability of quality materials, and whether they can be used for engineering. Sampling inspection is commonly used method.

(3) Storage and usage

The quality problems caused by material deterioration or misuse should be avoided in the management of storage and usage, such as the agglomeration of wet cement, corrosion of steel, and the mix of reinforcement with different diameters. On the one hand, the contractor should make reasonable arrangement to avoid overstocking lots of materials on site. On the other hand, materials should be stored with signs for the different categories, and with inspection and supervision on-site when being used.

4.1.3 Control of construction machinery and equipments

Construction machinery and equipments are essential facilities for the modern construction, reflecting the construction power of the enterprise, and having a direct impact on the project progress and quality. Actually, the quality control is to make the type and performance parameters of construction machinery and equipment match the conditions, technology and other factors of the construction site. (Liang Shilian)

- (1) The contractor should select construction machinery and equipment in accordance with advanced technology, economic rationality, production application, reliable performance and safety, with the applicability and reliability to a specific project.
- (2) The performance parameters should be made sure correctly in accordance with the requirements of construction and quality assurance. For example, the strength of tensile force of lifting jack must be larger than the maximum tension required in the procedures.
- (3) Construction machinery and equipment should be regularly calibrated, so as not to mislead the operator. Besides, mechanical equipment selected must be matched with the adapting operation workers.

4.1.4 Control of construction methods

Construction methods are reflected in the concentration of technical solution, process, testing methods, and arrangements of construction procedures for construction adopted by construction contractors. (Cheng Hu)

- (1) Construction program should be constantly refined and deepened with the progress of the project construction.
- (2) When selecting the construction program, some viable options of major projects should be prepared, presenting main contradictions, advantages and disadvantages, so as to discussion and comparison, then the best option will be selected.

(3) When developing programs for the major projects, key parts and difficult projects, such as the new structure, new materials, new technology, large-span, large cantilever, the tall structure parts, and so on, the possible construction quality problems and treatment should be fully assessed.

4.1.5 Environmental control

Creating a good environment will play an important role in guaranteeing the quality and safety of construction projects, achieving civilized construction, and setting social image of construction corporation. Control of construction environment includes not only the understanding, restriction, transformation and usage of natural environment, but also activities of creating working environment and environment management. (Cheng Hu)

(1) Control of the natural environment is to grasp data and information of hydrology, geology and meteorology of construction site, in order to establish construction plans and measures with the consideration of the characteristics and laws of the natural environment and actual conditions, to prevent ground and underground water affecting construction, and ensure the safety of underground pipelines of the surrounding buildings.

(2) Control of management environment is to learn the management relations of all participating construction units from the contract structure, then establish organizational system of on-site construction and integrated operation system of quality management. There are roles of mutual promotion and restraint, and coordinating operation between arrangement ensuring construction procedures and formation process of construction quality. In addition, the coordination, communication and good public relations are required with the neighboring residents or working sites, to acquire their necessary understanding and support.

(3) Control of working environment is firstly to do rational planning and management of construction plan, and arrange the layout of mechanical equipment, materials, components, roads, pipelines, and various large temporary facilities. Secondly, the various protective

measures should be taken, with clear signs, and the roads of construction should be unblocked. Third, before leaving the construction site, it should be cleaned up.

4.2 Quality control of construction process

4.2.1 The concept and contents

The quality of the construction process is the quality of integrated action due to human, material, machinery, process methodology and work environment, also known as process quality, which reflects the quality of products. In order to ensure the quality of construction project, the quality of each process must be controlled, which is the focus of quality control during construction. (Liang Shilian)

Process quality control is implemented on the process conditions for the activities (the quality input of process activities) and effectiveness of the process activities (the quality of sub-project). The following work should be focused on during process quality control.

(1) Determining the program of process quality control

On the one hand, specific measures to ensure quality of technology for the different processes, and the provision of inputting materials and the order of activities are required. On the other hand, the work flow and quality inspection system are needed.

(2) Controlling the quality of conditions of process activities actively

There are five main factors affecting the quality of process conditions: human, materials, machinery and equipments, methods, and the environment.

(3) Inspecting the quality of effectiveness of process activities in a timely manner

The implementation includes self-inspection, mutual inspection, the handover inspection of upper and lower working procedure, especially for hidden works and sub-items (Section).

(4) Setting the process control point (process management point) with key control

Process quality control points are major control objects determined for the key components affecting quality or weaknesses. Control points should be set correctly and implemented strictly.

4.2.2 Setting and management of process quality control points

The principle of setting quality control points includes:

- the important and key construction process and parts
- the construction process and parts without assured quality
- the construction position and parts with hard condition and technological difficulty
- the construction projects and contents with strict requirements of quality standards or precision
- the construction process and parts influencing the quality or safety of subsequent construction
- the construction sites and parts using new technology and materials construction

The management of process quality control points includes two aspects:

The design of measures of quality control points

- After choosing points for each segment, the control measures should be designed reasonable. Main steps and contents are as follows:
 - Listing the quality control points list
 - Designing construction flow chart of control points
 - Analyzing the processes to find the dominant factors
 - Setting the process quality control table, to make clear control ranges and requirements for the dominant factors
 - Working out work instruction assuring quality

- Drawing up network diagram, marking the measuring instruments, numbers, precision etc. in order to do accurate measurement
- Auditing the quality control points by the leadership of the designers

The implementation of quality control points

- Clarification. The design of control measures of control points should be explained clearly to the operation team, to make workers understand operating essentials.
- The quality controllers must give guidance, inspection, checking and acceptance on construction sites.
- Workers should do the operation according to working instruction, ensuring the quality of each aspect of the operation.
- The construction site should be checked seriously and regularly, and the data should be recorded.
- The analysis and improvement should be done constantly with the method of data statistics until the quality control points get qualified.
- Duties and responsibilities of workers and quality controllers should be clear in the implementation of quality control points.

Examples for setting process quality control points

The example of construction, typical one of the TCC's projects, is taken to illustrate the establishment of process quality control points.

Table 2: the list of setting quality control points

No.	Name	No.	Name
B-1	Prevention of the collapse of deep foundation	C-6	Synchronous masonry of mixed structure of interior and exterior wall
B-2	The control of perpendicular of reinforced concrete pile		
B-3	Compactness of sand	C-8	The strength of the test

	bedding course		block of concrete mortar
B-4	The colligation of independent base steel	C-9	Standard consevation of test block
C-1	The control of perpendicular of high-rise building	D-1	Floor of balcony
		D-2	Roofing paper
C-2	The control of floor elevation	D-3	Decoration of doors and windows
C-3	The construction of large formwork	D-4	The floor of fine aggregate concrete
C-4	Pouring and beating of concrete of wall	D-5	Painting of wooden products
		D-6	Brush of cement mortar
C-5	Bonding rate of brick		

It is shown in Table 2 the establishment of quality control points in each phase of construction. There are three main phases including the phase of base, construction and decoration, and each process of these phases is abbreviated as B-X, C-X and D-X respectively. Also, corresponding quality control point of each process is set.

Three representative control points are selected form Table 2, and a concrete analysis will be given for the contents and requirements.

Table 2(a): the contents and requirements of process quality control points – The colligation of independent base steel

Name of control point	Working contents	Operational staff	Standard	Tools	Checking frequency
The colligation of independent base steel	Prevention of the deviation of reinforcing bar	Construction workers Quality inspectors Technicians	The displacement of reinforcing bar is controlled within $\pm 5\text{mm}$, the space between stirrup $\pm 10\text{mm}$, not less than $35d$ of lap length, and 20mm of the thickness of protection layer with padding block.	Steel ruler Line hammer Visual measurement	Checking one by one

Technical requirements:

- (1) Snapping the line on the bedding layer first, after acceptance through technician's review, the steel can be colligated.
- (2) Firstly, the steel reinforcement of bottom plate and foundation beam should be colligated, then the inserted iron steel reinforcement finally.
- (3) At least three fixed hoops are needed on reinforcing appearance department.
- (4) The center line should be fixed in right position on the junction of basic plane and column, and the steel reinforcement should be controlled in a vertical position.
- (5) Construction workers and technicians should check the location and elevation.
- (6) When pouring concrete, the vibrated rod should not vibrate the steel reinforcement deviated.

- (7) Appearance of the reinforcement and the size of hoop should be in strict accordance with plan, and cannot be changed arbitrarily.
- (8) If necessary, the joint of steel reinforcement and base should be fixed by welding.

Table 2(b): the contents and requirements of process quality control points – Bonding rate of brick

Name of control point	Working contents	Operational staff	Standard	Tools	Checking frequency
Bonding rate of brick	Bonding rate of brick masonry should be larger than 80%	Technicians Construction workers	According to standards and the requirements of brick masonry, 3 pieces of brick each group should be bonded together, and the average rate is not less than 80%	100 grid Visual measurement	Sampling check

Technical requirements:

- (1) The consistency of brick masonry mortar should be controlled between 7 cm and 10 cm.
- (2) Water holding capacity of mortar should be good. (Coursing degree of mortar should be less than 2 cm)
- (3) The error of the accuracy of each raw material (including sand, lime paste, electric gypsum, coal powder, etc.) should be controlled within $\pm 5\%$, and that of organic plasticizer should be controlled within $\pm 1\%$. All materials need to be weighed and measured.
- (4) The time period mixing mortar should not be less than 1.5min, and using time should not be more than 2-3 h.

- (5) The blocks should be moisture with water, and the moisture content should be 10%-15%.
(Winter construction should be considered.)
- (6) The bonding rate of mortar and brick should be increased by using trowel during the operation of walling.

Table 2(c): the contents and requirements of process quality control points – Construction of floor of balcony

Name of control point	Working contents	Operational staff	Standard	Tools	Checking frequency
Construction of floor of balcony	Prevention of flashing and water leakage of balcony floor	Construction workers Technicians Quality inspectors	Quality Evaluation Standards of Construction Engineering Bureau in China	Level ruler Extension lead Visual measurement	Checking balcony one by one

Technical requirements:

- (1) The elevation of the wall should be checked to be flat before balcony board being hoisted.
- (2) After installation, the balcony board should be checked whether there is the phenomenon of flashing and pouring water.
- (3) The slope of flashing should be controlled with leveling instrument, and the line should be set on the wall and board, to make sure the right flashing of water.
- (4) Before inbuilding the water hopper, the reserved holes should be cleaned. And if the surface of holes is too smooth, that should be chiseled roughly.
- (5) When inbuilding, the position should be watered to be wet, and embedded with cement mortar by 1:2 roundly.

- (6) Brushing the balcony should not be in the same construction with inbuilding water hopper.
- (7) After finishing brushing the balcony, the flashing of water should be checked by leveling instrument. If it does not meet the requirements, it must be reworked.

4.2.3 Quality pre-control of project

The quality pre-control of project is the prior analysis of the quality problems and potential problems which may occur in the quality control point or sub-projects, including the reason, and corresponding preventive measures, to realize the active control to the project. (Liang Shilian)

4.2.4 Protection of finished product

In the construction process, some sub-projects have been completed, while other sub-projects are still on construction, or, in the construction process of sub-projects, some parts have been completed, while other parts are still on construction. In this case, the completed projects or parts should be adopted proper protecting measures, to avoid damage or pollution because of the lack of protection, affecting the overall quality of projects. (Liang Shilian)

According to the characteristics of different projects, the protecting measures are different, but the construction sequence should be arranged reasonably to achieve the purpose of protecting finished product.

- (1) Protection: Taking various protective measures in accordance with the characteristics of the objects to be protected

For example, the easy touch parts can be reinforced by protective bar or groove cover iron. Windows and doors can be fixed by additional wedge after installation.

(2) Parceling: Wrapping up the objects to be protected against damage and contamination

For example, the columns with marble cladding can be wrapped and bundled with boards. Windows and doors can be wrapped by plastic cloth.

(3) Cover: Covering the surface preventing from blockage or damage

For example, after installation, floor drain should be covered to prevent from others fall into it and make it blocked. The projects need sun or freeze protection, and for heat conservation and others. It should be taken appropriate measures.

(4) Closing: Closing partially for protection

For example, after refuse chute being completed, the entrance should be closed to prevent the construction debris blocking the chute. After decoration, the room should be closed to avoid damage because of unwanted entries.

(5) Reasonable arrangement for the construction sequence: Arranging the construction sequence of different workplaces in order to prevent the following process from damaging or polluting the prior process

For example, when decorating the room, the wall should be whitewashed or painted prior to the installation of the lights, in order to prevent the lights from being damaged or polluted by painting. As well as the sequence of decorating the platfond and floor, the platfond should be decorated before the floor.

4.3 The method of quality control

4.3.1 Quality control by statistical methods

The use of statistics is essential in interpreting the results of testing on a small sample. There are two types of statistical sampling which are commonly used for the purpose of quality control in batches of work or materials (Quality Control and Safety During Construction):

- (1) The acceptance or rejection of a lot is based on the number of defective (bad) or nondefective (good) items in the sample. This is referred to as sampling by attributes.
- (2) Instead of using defective and nondefective classifications for an item, a quantitative quality measure or the value of a measured variable is used as a quality indicator. This testing procedure is referred to as sampling by variables.

The construction of control charts is based upon statistical principles. The charts used in this research require normal distribution of data. The centerline in Figure 3 could represent an estimate of the mean, standard deviation or other statistics. The curve to the left of the vertical axis should be viewed relative to the upper and lower control limits. There is very little area under the curve below the lower control limit (LCL) and above the upper control limit (UCL). This is desirable as areas under a curve for a continuous distribution represent probabilities. Since a process or a property is out of statistical control when a value is outside the control limits, quality control requires that the probability for such an event to occur is small. (Application of Statistical Quality Control Charts and Geostatistics to Soil Quality Assessment in a Semi-Arid Environment of South-Central Iran)

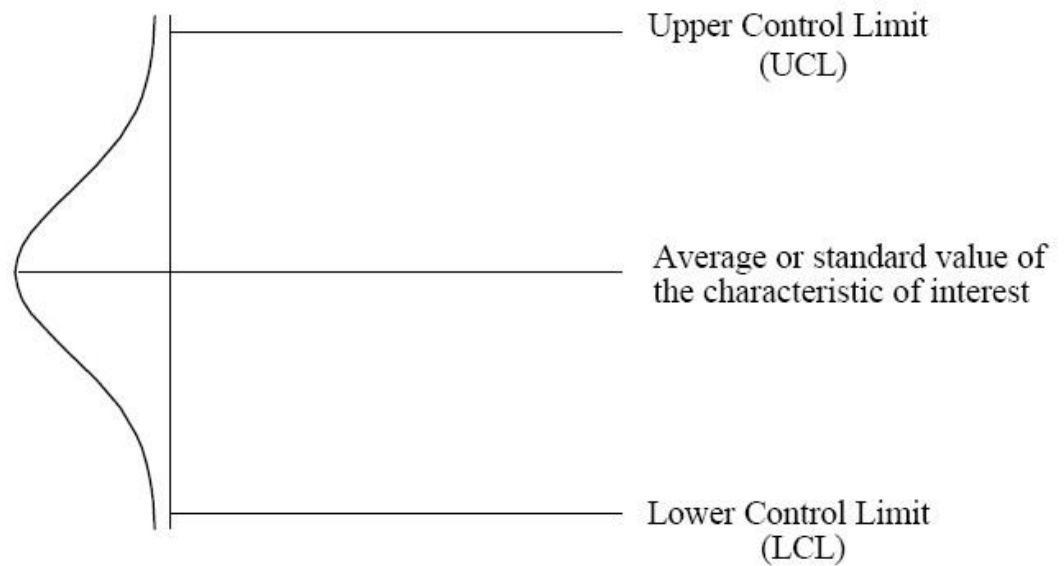


Figure 3. Basic form of a control chart (Application of Statistical Quality Control Charts and Geostatistics to Soil Quality Assessment in a Semi-Arid Environment of South-Central Iran)

4.3.2 PDCA

TCC has adopted a kind of scientific management procedure and method to do quality control of construction, named PDCA Cycle, which is composed of 4 stages of P (plan), D (do), C (check), A (action). The detailed procedures of PDCA are introduced as follows.

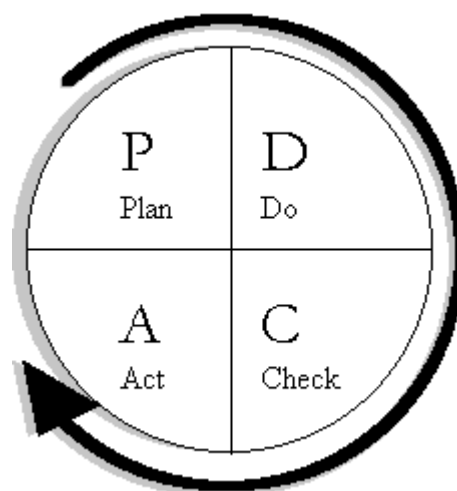


Figure 4. Plan-Do-Check-Act Cycle (PDCA cycle)

(1) Plan

The first step is to analyze the status quo of quality, and identify the quality problems. For that, first of all, the common quality problems of enterprise-wide should be analyzed, which frequently occur on construction. Then, for the projects with difficult and complex techniques, strict quality requirements, or being applied of new techniques, new technology, new structure and new materials and so on, the problems should be reflected according to lots of data and information, through the way of mathematical statistics.

The second step is to analyze the causes arising in quality management and the influential factors. This step is also based on large amounts of data, and the discussion for the relevant problems is necessary. Finally, the cause-and-effect diagram should be drawn.

The third step is to identify the main factors affecting the quality. There are two kinds of methods, making use of mathematical statistics and diagrams, and adopting the ideas of relevant discussion when the data is available with difficulty or can't be acquired in the limited time.

The fourth step is to work out the measures to improve the quality, propose the action plan and estimate the results. During this step, the questions of "5W1H" should be considered and answered. 5W1H means: Why should these measures be taken? What effects? Where (which procedure, which process, which segment) should be implemented? When will the measures be taken and completed? Who is responsible for the implementation? How can that be done well?

(2) Do

This stage includes just one step. That is to organize the implementation of quality plan and measures. Firstly, determining the plan, including organization, techniques and materials, some relevant workers should participate in the training, practice and examination. Secondly, the implementation of plan should rely on the quality management system.

(3) Check

This stage is to check the effects of measures taken. In other words, that is to check whether the operation is taken according to the requirements of plan, and identify which is effective and which is not.

(4) Act

The first step of this stage is to sum up experience and consolidate achievements. After check of previous step, the good experience of implementing effective measures should be concluded, through revising relevant documents, regulations, standards and rules of quality management, to strengthen the accomplishment.

The second step is to raise the outstanding issues. Through the inspection, the measures without obvious effects or inconformity measures should be reflected to the next cycle as the remaining issues.

PDCA Cycle is ongoing. The quality goals can be realized and some problems can be solved in each cycle, so that the quality can be improved.

4.4 Analysis and treatment of quality problems of construction

Construction quality problems are generally divided into defects, common problems, and accidents. Construction quality defects refer to the phenomenon that technical indicators of construction fall short of the allowance of technical standards. Common problems refer to the common quality injury affecting construction structures, functions and form. Quality accidents refer to the quality damage with larger loss and influence of the safety of construction structures, functions and form, in the procedure of construction or after delivery for use. There are four distinguishing features (Liang Shilian):

- a large number of economic loss
- sometimes resulting in casualties
- serious consequences, affecting the structural safety
- reconstruction without downgrading use or restoration

4.4.1 The analysis of reasons for construction quality problems

The forms of construction quality problems were different and varied, but the reasons can be mainly summarized in the following aspects.

1) Problems concerning the construction procedures and regulations

These problems include undocumented design, construction without drawing or not according to drawing, delivery for use without final acceptance, undocumented construction, unauthorized subcontractors, and unauthorized modification of design etc.

2) Problems of design and calculation

For example, drawing was applied blindly, or structure program was adopted incorrectly. There were also the problems that calculating diagram was inconsistent with actual force, or load value was too small, as well as the error of internal force, and possible calculating errors etc.

3) Substandard materials and products

4) Out of control of construction and management

- Drawing was applied for construction hastily without inspection, or blind construction was taken being unfamiliar with the drawing.
- The design was modified without permission from design department, or the construction was not on the basis of drawing.
- The construction was not following the norms of construction quality acceptance and operating procedures.
- The operating workers were lacking basic knowledge.
- Construction management was in disorder, and the construction sequence was erroneous. Technical disclosure was unclear, and inspection and acceptance was neglected.

5) The influence of natural conditions

Because of the long cycle of project, and open-air operation, construction was impacted greatly by natural conditions. For example, all of temperature and humidity of air, wind, waves, floods , rain and sun may be the incentive for quality accidents. So the prevention and effective measures should be taken during construction.

6) Improper use of facilities

4.4.2 Processing procedures of construction quality problems

After construction quality problems occurred, the following procedures can be handled, as shown in Figure 3.

As the indication from Figure 5, the general segments and steps of processing procedures are shown. The detailed contents and measures will be introduced in six aspects.

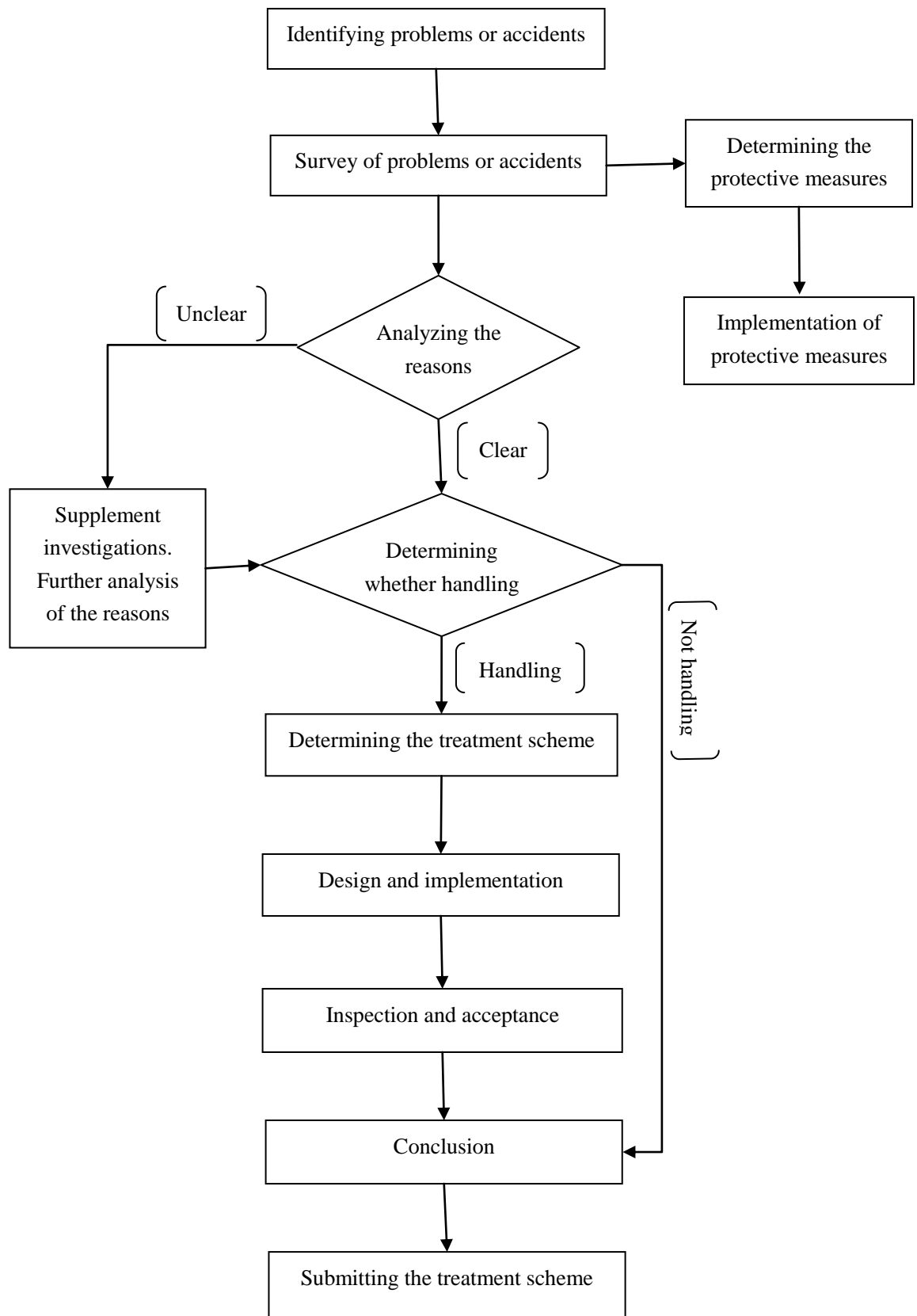


Figure 5. Processing procedures of quality problems

(1) When identifying the quality problems or accidents, all construction parts with quality problems and related parts and the next construction procedure should be stopped, if necessary, and appropriate protective measures should be taken. At the same time, the actual condition should be reported to the competent authorities.

(2) The main purpose of investigation is to define the scope, extent, properties, impact and reasons in order to provide the evidence for problem analysis. The investigation is striven to be comprehensive and objective.

(3) The reasons should be analyzed on the basis of investigation, in order to do the correct judgments. The analysis of reasons for quality problems is the base to determine the treatment scheme. Thus, correct measures are derived from correct judgments on the cause of the problems. Only with the help of detailed and in-depth analysis of the data from investigation, the real cause of the problem or accident can be found out.

(4) The development of treatment scheme for problems or accidents is based on the analysis of reasons. If some problems cannot be understood temporarily, and the results won't get deteriorated in a short time, the further investigation and observation can be continued, in order to get more information, which will be helpful for further analysis and finding out the reasons, to facilitate the development of scheme.

The principles of treatment scheme are safety and reliability, technical feasibility, economic rationality and meeting the construction functions and using requirements.

(5) The problems or accidents should be handled according to the determined scheme.

(6) After the treatment, the results should be strictly checked, identified and acceptance inspected. Then the supervision engineer should write reports, and submit them to competent authorities.

4.5 Determination of treatment scheme of quality accident

4.5.1 The basis of treatment

To handle quality problems, the reasons should be analyzed firstly, and then the correct treatment scheme or decisions should be made. It takes detailed and accurate information for the basis and foundation of decision-making. For the general treatment of quality accident, the following information is necessary.

(1) Construction drawings related to the quality accident.

(2) Information, data and records related to construction. Such as test reports of construction materials, inspection records of all kinds of intermediate products, test reports and construction records.

(3) Analysis reports of accident investigation normally should include:

- Circumstances of quality accident

They include occurrence time, location, accident description, the record of observations, the trend of the accident, and whether the situation is being stabilized and so on.

- Properties of quality accident

It should be distinguished what is the problem like. Is it a structural problem or a general problem, internal substantive issue or surface issues? Whether it needs to be handled timely and whether protective measures are needed?

- Causes for quality accident

The main reason for the accident caused by quality should be clarified. For example, cracks in concrete structure are due to the uneven settlement of foundation, or temperature stress, or because of attack or vibration before the form removal, or because the power of bearing structure itself is inadequate. In this regard, the convincing data and illustration should be accompanied with.

- The assessment of quality accident

It should clarify how the accident impacts on the function, use requirements, mechanical properties of structure, and safety of construction. The measurement records, checking data and test data should be accompanied with.

- The comments and demands of design, construction and use organization for the quality accident
- The situation of involving staff and primary responsibility

4.5.2 The treatment scheme of quality accident

The treatment scheme of quality accident should be carried out based on the proper analysis and judgment of the cause of the accident. According to the case of quality problems, there are four different types of treatment options.

(1) Repair treatment

This is one category of the most commonly used treatment options. Usually, although the quality of some parts of the project does not achieve the required norms, standards or design requirements. In other words, there are some flaws, it can also be up to the required standards after repair, without compromising function or appearance requirements. In this case, the decision of repair treatment can be made.

(2) Rework deal

When quality of the project does not meet the required quality standards or requirements, and there are obviously serious quality problems, with significant impacts on the use and

safety of the structure, besides the defects cannot be corrected through the repair approach, the decision of rework deal can be made.

(3) Use restrict

When quality of the project cannot be guaranteed to reach the use requirements of safety by the repair treatment, but rework deal cannot be done in the actual situation, restrictions on the use can be made.

(4) No treatment

The quality of some projects do not meet quality requirements or standards, but it is not very serious, and has few effects on the use and safety of the structure, after analysis, argument and careful consideration, the decision of no special treatment can be made. The contents for this are:

- It doesn't affect the structural safety and use.
- It has some slight quality problems, but can be made up after follow-up processes.
- After review and check, it still meets the design requirements although with arisen quality problems.

4.6 Identification and acceptance of treatment of quality accident

Does the treatment of quality accident achieve the intended purpose? Is there still hidden danger left? These should be secured through identification and acceptance. Inspection and appraisal of quality accident should be taken strictly in accordance with specifications and provisions of the relevant standards. If necessary, in order to make definitive conclusion for the results of treatment of quality accident, the necessary data is required through the methods of actual measurement, test and detection of instrumentation.

The conclusion of inspection and identification can be summarized as follows:

- The problems have been solved, and the construction can be continued.
- The risks have been eliminated, and the safety can be ensured.
- After the repair and treatment, the project can fully meet the requirements.
- The project is basically meeting the requirement, but there should be additional restrictions for use, such as limiting the load, etc.
- The durability should be concluded.
- The the impact on appearance should be concluded.
- If it is difficult do make a conclusion in a short time, the further test and observation can be taken.

After treatment, a supervision engineer should submit the treatment report, including an accident investigation report, an analysis of accident reasons, a treatment basis, a treatment scheme, methods and technical measures, a variety of original records and information on the construction process, inspection and acceptance records, conclusions and others.

5 Conclusion

Through the research, there was learnt the function and importance of quality control. Quality management in construction is a road map to business success through quality. Among the many topics it covers are: a step-by-step approach to creating a quality management system that is right for your company; how to include all your stakeholders in the quality process; how to identify and map your key processes; how to use your system to help market your business and stay competitive; how to monitor and improve ongoing business performance and much, much more. (Construction skills)

The aim of the research on the quality control is to find out the shortcoming of quality management of enterprise, then to make progress through the research, so as to improve the quality of product, work, and service, while strengthen the quality management system, and raise the overall level of quality management. For a construction organization, the quality of construction project is the protection of all the work. In order to establish the corporate image and strengthen competitiveness, the quality of construction is required constant improvement.

There are still some suggestions for the quality management and control of construction project.

(1) The mathematical methods can be used for quantitative control and management of project quality. It can make quality management more quantitative, objective and scientific, which is advantageous to constantly improving the construction quality and raise the level of construction quality management.

(2) The review of the construction organization and workers should be strengthened, and the qualification management should be strict. The quality and technical operation of workforce should be improved through training, and the continuing education of technical staff should be encouraged.

(3) The systematic quality management system should be applied. The quality of each process and project can be ensured through systematic planning, control and inspection. The waste of workforce, machinery, materials and other costs can be avoided, as well as the schedule delays. It has been found out that the scientific quality management system can ensure the rational allocation of project resources, and make the project run on the preconcert quality objectives, so as to achieve the effect of project quality control.

(4) The quality management of the whole process of project construction should be paid more attention, including the phase of pre-construction, construction and completion. The consciousness of quality control in the phase of project quality plan should be strengthened, and the focus on the inspection after completion should be transferred to the planning and process control of pre-construction.

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Appendices

Appendix 1. Main qualification certificate of TCC

- Prime Contracting to Construct and Install Various Chemicals and Petrochemical Projects (Grade A)

- Prime Contracting to Construct Municipal and Utility Projects (Grade A)

- Prime Contracting to Construct Electro-Mechanical Installation (Grade A)

- Prime Contracting to Construct Various Industrial and Civil & Architectural Projects (Grade A)

- Prime Contracting to Construct Metallurgical Projects (Grade B)

- Professional Contracting to Construct Environment Protection Works (Grade A)

- Professional Contracting to Perform Pilling and Ground Improvements (Grade A)

- Professional Contracting to Construct Steel Structure Works (Grade A)



- Professional Contracting to Perform Piping and Pipeline Works (Grade A)
- Professional Contracting to Install Chemical and Petrochemical Equipment & Pipe Works (Grade A)
- Professional Contracting to Perform NDT Works (Grade A)
- Professional Contracting to Construct Architectural Decoration and Fitments Works (Grade B)
- Professional Contracting to Construct Architectural Curtain Wall Works (Grade C)
- Professional Contracting to Construct Metal Doors and Windows Works (Grade C)
- Foreign Economic Cooperation Business Operation Qualifications
- Qualification Certificate For Import/Export Enterprise
- THE "U" Authorization for Shop Manufacturing and Field Assembly in Compliance With ASME Codes
- Pressure Vessel Manufacturing License (Category I, II, III)
- Pressure Vessel Design License (Category I, II)
- Steam Boiler Installation License
- Pressure Piping (GA, GB, GC) Installation License
- Piping Components Manufacturing License

Appendix 2. The main management segment and controlling contents in each stage

Stage	Main management segment	Main controlling contents
Contract	Appraisal of tender documents	The level of company's ability satisfying the construction
	Appraisal of contracts	Quality target of contracts
	Management of	The explanation of contracts and changes
Construction preparation	Quality planning	Quality goal setting and analysis of projects
		Quality plan or preparation of design of construction organization
		The development of quality assurance
		Quality control point setting
		Identification of environmental conditions
	Mobilization of resource	The recognition and training of personnel
		Requirement planning of labor
		Requirement planning and inspection of machinery and equipments
		Selection of providers
		Mobilization of funds
	Documents control	Documents design
		Technical specifications

Stage	Main management segment	Main controlling contents
		Enterprise standards (management standards and technology standards)
		Owners providing documents
	Technical preparations	Design details
		Review of drawing
		Design (program) of construction organization
		Other process documentation
		Technology details
	Preparing quality records form	
	Preparation for working site	Temporary construction site
	Construction	Control of measurement equipment
Examination and test of validity of measurement equipment		
Confirmation of qualification of recognized organization		
Systemization and custody of measuring		
Process control		Technology details
		Document control
		Status of inspection and test
		Self-test of process
		Intermediate transfer

Stage	Main management segment	Main controlling contents
		Process control
		Control of disqualified product
		Corrective and preventive measures
		Machinery and equipment management
		Quality records and management
		Protection of construction production
		Feedback and data analysis
	Communication with customers	Information exchange
		Identification of customer's demands
Control of process service		
Completion	Test program and implementation	Implementation according to the program
	Quality management records	Full and completed records of the content
	Protection and management of	Pre-control, reward and punishment
	Management of project handover	
	Service control	Modification of part of the construction and warranty service
After service	Management of quality re-visiting to customers	Implementation of re-visiting scheme and occasional re-visiting

Stage	Main management segment	Main controlling contents
	Warranty service management	Completion of warranty items
	Information management (customer's requirements as inputting information of management review)	

Appendix 3. Quality inspection and acceptance records

Project Name		Name of sub-projects		Acceptance part	
Construction organization		Professional foreman		Project manager	
standard name and number of implementation of construction					
Subcontractor		Sub-project managers		Leader of construction group	
Master project	Quality acceptance requirements	Check and assessment records of the construction organization			Inspection records of supervision
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
General Project	1				
	2				
	3				
	4				
Evaluation of test results of construction organization	Signature of professional quality inspectors: Date:				
Inspection results of supervision	Signature of supervision engineer (technical leader of construction organization): Date:				

Appendix 4. Completion inspection records of project quality

Project name		Type		Construction Project	/
Construction organization		Technical leader		Starting date	
Project manager		Project technical manager		Completion date	
1	Partitioned project	Total parts Parts meet standards and design requirements Parts not meeting standards and design requirements			
2	Verification of quality control data	Total items Items meeting requirements Items not meeting requirements			
3	Verification and sampling results of security and main use function	Total projects Projects meeting requirements by the rework treatment			
4	Perception quality acceptance	Total items Items meeting requirements Items not meeting requirements			
5	Comprehensive inspection result				
Participating organization in inspection and acceptance	Use organization	Supervision organization	Construction organization	Design organization	
	(Signature) Project leader Date	(Signature) Chief supervision engineer Date	(Signature) Project leader Date	(Signature) Project leader Date	